# The Canadian Entomologist

## Remarks on a Possible Biological Control Program with the Weed *Acanthospermum hispidum* D.C.

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It is well known that the accidental introduction of some plants into certain parts of the world has later led to noxious weed problems of varying degrees of acuteness.    Control of such alien plants by cultural or chemical methods may be unsatisfactory or economically impracticable and recourse is made to biological methods in the form of insect enemies etc.    It was in circumstances of this nature that the Government of Nigeria requested the C.I.B.C. to investigate the possibilities of the biological control of the weed *Acanthospermum hispidum* D.C. Despite the discouraging facts that the weed is an annual and related to plants of economic importance in the family Compositae, and that the entomological method is appropriately regarded as being of very restricted application in these instances, the nature of the problem for Nigerian agriculture was such that a preliminary investigation of the status of the plant in its native South American home seemed warranted.

The plant is a member of the Melampodioid Heliantheae, which tribe includes notorious bur weeds such as *Xanthium* of Australia and North America. Blake (1921) states that all eight known species of the genus *Acanthospermum* are natives of the Americas with two (*A. hispidum* and *A. australe* Loefl.) now widespread in the Old World as scattered introductions.    *A. hispidum* also occurs as a weed in Africa south of the Sahara (Phillips 1938); and in parts of Central America, the Lesser Antilles, the United States and Hawaii.    It is also gazetted a noxious weed in Queensland, Australia (White 1941).    Dispersal was probably by means of the spiny fruits, entangled in wool of sheep etc.    Recorded by Blake from every country in South America except Chile, he considers it native over at least part of that vast area; in conversation in 1952 he stated that on the basis of his records coastal Brazil, Venezuela, and Colombia could be regarded as probable centres of dispersion.

### The Nature of the Problem in Nigeria

The following information is based on annual reports of the Nigerian Department of Agriculture, and discussion and correspondence with various officers of the Department.    The plant reaches the status of a pest only in the most northerly parts of the country, that is, in the provinces of Sokoto, Katsina, and Kano, which largely fall within latitudes 11° and 13.50°N.    South of about latitude 9°N. the natural vegetation becomes much more vigorous, so that competition confines the weed to roadsides, paths, clearings etc.    In reply to a questionnaire (1953) the Principal Agricultural Officer interpreted the general picture " . . . . . as an interaction between ecology on the one hand and human and animal population density on the other.    The ecological factor is that the weed cannot persist where natural vegetation consists of strong herb, shrub or tree growth. There are thus very few places (except in the more barren parts of the extreme north) where, in the absence of human activities, the weed could persist.    This fact is reflected in the general common occurrence of the weed in market places, along roadsides and tracks and particularly cattle tracks.    Apart from this, it is found in grazing lands where the land has recently been cultivated (i.e. climax vegetation not yet developed) or where density of human population (and there-

fore overshort fallows) and/or of animal populations (and therefore overgrazing) prevents the growth of a strong vegetation." The foregoing situation is of concern because cattle, sheep and goats are of importance for the internal economy of Nigeria. Cheese and butter production for local consumption is centered in the north while the herds are valued also for the hides which have for years been exported on a large scale to European and American markets.

*A. hispidum* thus constitutes a problem only in that part of Nigeria which Keay (1949) places in the Sudan vegetation zone of the savanna region of West Africa and long recognized for its characteristic climate etc. This geographical region has a very well marked monsoonal change of wind and weather. There is the virtually rainless season of at least five months (November to March) dominated by the dry northeast winds (Harmattan) from the Sahara. In this period average relative humidity figures for representative stations are extremely low, often falling to 10% (Table 1). Temperatures reach their maxima in

TABLE 1
Climatic Data.* Sokoto, N. Nigeria

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Monthly Rainfall Inches | 0 | 0 | .03 | .42 | 1.97 | 3.52 | 5.84 | 9.31 | 5.73 | .51 | 0 | 0 | 27.33 |
| Mean Relative Humidity | 12 | 16 | 10 | 17 | 29 | 41 | 55 | 68 | 63 | 41 | 16 | 17 | 32 |
| Monthly Means Daily Max. Temperatures | 91.6 | 95.5 | 100.7 | 104.9 | 102.8 | 97.6 | 90.7 | 86.3 | 89.4 | 96.1 | 97.7 | 92.6 | 95.5 |
| Monthly Means Daily Min. Temperatures | 59.6 | 62.9 | 70.2 | 76.2 | 78.6 | 76.4 | 72.5 | 72.1 | 71.6 | 70.5 | 64.3 | 59.8 | 69.6 |
| Mean Monthly Temperature | 75.6 | 79.2 | 85.5 | 90.5 | 90.7 | 87.0 | 81.8 | 79.2 | 80.5 | 83.3 | 81.0 | 76.7 | 82.5 |

*From: British West African Meteorological Services, Lagos.

March, April and May, with the change of season characterized by violent dust storms ("dry tornadoes"). The southwest trades now bring the weather of the Guinea Coast—saturated air, heavy rains, thunderstorms—to northern Nigeria. Rainfall periodicity is therefore pronounced, with moderate to heavy falls occurring from May to September, and August maxima for localities such as Sokoto, Katsina, and Kano.

### A. hispidum in South America; Its Status and Insect Enemies

Judging by the few specific references in the literature *A. hispidum* in South America has received little attention from botanists etc. other than the recording of its distribution there. There is, for example, no mention of the plant in the standard works of Pittier (1926), Perez (1936), Herrera (1939), Robledo (1940) and Uribe (1941), which include information on agricultural and medical applications of the local fauna. This omission, together with the absence of vernacular names, may be taken as good indication that the plant is rare in (or perhaps alien to) Peru, Venezuela and Colombia. In Argentina Molfino (1945) has recorded it as a minor pest of subtropical crops such as cotton in the northern provinces of Tucuman, Salta, Chaco, Missiones, etc. Bennett and Costa (1940) refer to the

plant, known locally as "Carrapicho de Carneiro", as occurring in considerable abundance in cultivated areas of the Sao Paulo area of southern Brazil. It is in fact a common weed in various crops, and a proven wild host carrier of at least two viruses attacking numerous commercially important plants—tobacco, tomato, sugar beet, flax, etc. In northeast Brazil Menezes (1949) and A. A. da Costa (1949) list *A. hispidum* as a common weed in the Bahia region, where the local inhabitants are said to use it in various ways for its actual or supposed medicinal properties.

The foregoing data, supplemented by that from correspondence, served as a basis for an exploratory survey in South America between March and August 1953 to determine the status of the plant there and the possibilities for a biological control programme in Nigeria. The planning of the itinerary was complicated by the facts that the weed is an annual and that it was necessary to survey territories lying roughly between latitudes 25°S. and 12°N. A satisfactory solution was found by starting survey work in southernmost areas in March, where the advanced summer season assured maturity of any plants present, and then proceeding north to the equator and beyond.

Only brief attention was given to the southern Chaco area of Argentina because of its extra-tropical location, but *A. hispidum* was easily found in all sections of the Tucuman-Santiago del Estero region. In Tafi Viejo dense stands varying from a few to hundreds of acres of wasteland or pasture were observed whereas to the east in the more arid territory of Santiago del Estero Province it was noted only as roadside patches or scattered in cotton. Flowering and fruiting plants in roadside and wasteland stands bore good numbers of the aphid *Macrosiphum lizerianum* Blnchd. but the populations were not heavy enough to cause death and the attacked *Acanthospermum* seemed to produce the normal quota of burrs. Heavy stands in permanent pasture appeared much healthier and free from attack by aphids etc. This aphid is recorded as a minor pest of lettuce, sunflowers, etc. in Argentina. Some leafhoppers—*Agallia* spp.?—were observed but coleopterous and lepidopterous leaf and stem feeders were singularly absent. In Santiago del Estero a few plants were found heavily infested with red mites (Tetranychidae). There was no evidence of flower and seed attack by insects.

The most interesting observation in the Tucuman region was the presence of plants in which flowering and seeding had been totally inhibited. In some stands in wasteland approximately half the plants were of this type, and it was not unusual to find individual specimens with some of the stems so affected, the other parts being normally green and bearing flowers and fruit. The general effect of such "diseased" plants was a yellowing of the leaves and an intense proliferation of the terminal shoots, suggesting to the writer a virus attack. However, Argentine and Brazilian plant pathologists rejected such diagnosis, and Dr. Costa of Campinas, Brazil, who has published on virus diseases of this plant, stated that he knew of no such pronounced effects from virus attack. The causes of this sporadic flower and fruit inhibition are therefore not known but the problem clearly merits investigation.

In Brazil extensive travelling was done in the State of Sao Paulo in late April and early May because of the statement of Bennett and Costa (loc. cit.) as to the plant's incidence there. It was therefore not surprising to find that the abundance of the weed was impressive although infestations of the order later seen in all types of cultivated crops had not been anticipated. In the environs of Sao Paulo and Campinas scattered patches on roadside and wasteland were common, while dense stands of fruiting specimens were noted in maize, soybean and castor bean

experimental plots of the Instituto Agronomico, Campinas. Full appreciation of the pest status of this plant was gained on a 200 mile field trip from Campinas to Riberao Preto, a city in the northern section of the state at approximately latitude 21°S. It was exceptional to see the weed in pasture, but in young maize, cotton, citrus and castor bean the stands were sometimes such as to practically smother out the crop. Farmers and agricultural experts acknowledged it to be a tremendous pest, usually controlled by a horse or mule drawn hoe, but its importance is shrugged off with the observation that there are more pressing problems. The natural primitive vegetation of this region is a mixed savanna-scrub forest known as "Cerrado", wherein competition is apparently strong enough to exclude *Acanthospermum*. The influence of competition was also seen in some large acreages of maize interplanted with beans (feijao) as the weed was not observed in these habitats.

In spite of the great abundance of the plant in this part of Brazil not a single instance was observed of insect or other enemies reaching destructive proportions. In fact the insect fauna of *A. hispidum* here was extremely poor. *Agallia albidula* Uhl., the leafhopper virus vector reported on by Bennett and Costa (loc. cit.), was common, as were various species of aphid of the genus *Macrosiphum*. Occasionally a few lepidopterous or coleopterous eggs were found on leaves but their presence was apparently accidental since no damage by insect feeders was observed on thousands of plants in the same vicinity. A dead plant on wasteland in the outskirts of Sao Paulo city contained a stem boring coleopterous larva but this could not be reared to maturity and a sustained search for additional material was unsuccessful. Examination for flower and fruit attacking insects was equally unproductive, perhaps because no satisfactory arrangement could be made for holding this material the necessary extensive periods.

The next more northerly State of Minas Gerais was surveyed in mid-May at Belo Horizonte, Sete Lagoas and surrounding areas, which are situated inland approximately 300 miles from the coast between latitudes 19° and 20°S. The status of *A. hispidum* and the extent of its attack by insects etc. did not differ materially from those outlined for Sao Paulo; noticeably heavy stands of mature plants were observed in cotton and young sugarcane. Botanists at the Instituto Agronomico, Belo Horizonte, considered the weed a "planta invasora" and not native to Brazil in view of its predilection for wasteland, roadsides, and cultivated crops.

The Sao Salvador region, Bahia, at latitude 12°S., was the source area for the original specimens of *A. hispidum*. In June roadside and wasteland infestations of the plant in flowering and fruiting stages were as abundant as in more southern parts of Brazil. It was particularly common on wasteland a few hundred yards from coastal sand dunes at the villages of Ondina and Itapoan, while for the first time dense stands were seen in a belt of coconut palms.

At Sao Goncalo dos Campos and Feira de Santa Ana, localities in interior Bahia State about 100 miles northwest of Sao Salvador, the prevalence of the weed near centres of human population was again very evident but it could not be found in the primitive vegetation of strong growth still dominant in much of this tropical zone. It was an obvious pest in cultivated crops of young cassava, maize, peanuts etc., and the abundance of the weed such that local farmers and advisers thought the visit of the writer actually concerned with some sort of commercialization of the plant rather than a search for controlling agents. A noteworthy feature in the area was the presence of numerous small mature plants, often of less than three inches height, yet bearing apparently viable seeds.

Search for insect enemies was again unproductive. An occasional plant was noted with a damaged leaf, and in a few cases flower heads had been practically devoured, but the only insect material collected was two geometrid larvae feeding on *Acanthospermum* in a peanut crop at Sao Goncalo, and an undetermined leaf and stem feeding aphid. These enemies were obviously accidental feeders on the weed in these habitats. Nothing was secured from flowers and fruit held in the Instituto Biologico, Ondina, for some months.

In June at the height of the wet season *A. hispidum* plants of all ages were observed in the environs of Recife, Pernambuco (latitude 8°S.), and again the weed was abundant in corn and bean crops even in the wet coastal belt. Specimens on wasteland within one hundred yards of the sea in suburbs of Recife were the largest and healthiest seen in South America. Local agricultural workers reported the plant a cotton pest in the dry interior "calamity zone" of southern Ceará etc., but exploration into that section terminated because of bad roads at Vitoria, a town forty miles west of Recife and still within the wet zone.

In the wet Recife area aborted flower heads and fruits were seen in fair numbers, but no insects were obtained by dissection or holding of samples for some months. It is therefore doubtful if insect damage produced these effects. Injury by leaf and stem feeders here also consisted only of an occasional partially devoured leaf, and it was clear that no specific enemies of this type were present at the time of survey.

Exploration in Brazil was terminated with an inspection of the Fortaleza-Maranguape area of northern Ceará. In this region, at latitude 4°S., *A. hispidum* was as abundant as elsewhere in Brazil and known under a variety of vernacular names such as "Retirante" and "Delegado". In this dry section wilting and drying plants due to the drought were common but no insect attack was observed. Local workers claimed that the weed was of similar.incidence in Maranháo and other states near the Amazon estuary.

In Venezuela survey was restricted to the Chacao plain in the vicinity of Caracas, the coastal area of Maiquetia, La Guiara, etc., and finally the environs of Maracay, all localities from which *A. hispidum* had been recorded by botanical collectors. Search in mid July in these areas in habitats known to favour the plant did not produce a single specimen except at San Mateo, a small village about 20 miles east of Maracay where a few scattered fruiting plants were located in a dry river bed. No other stand was seen in the parts of Venezuela visited although numerous corn, sugarcane, and other crops were examined. This was a remarkable contrast with the position in Brazil, and particular attention was paid to the few plants found at San Mateo. However, they were free of insects and diseases, but this is not necessarily representative of the situation in Venezuela since search in this part of South America was inadequate.

In Colombia a week's search for *A. hispidum* in the dry scrub forest and wet savanna vegetation typical of the Barranquilla-Sabanalarga-Puerto Colombia region of the lower Magdalena Valley was completely negative. Local herbarium records indicated that the plant was known in this area, but no specimens were found in habitats closely similar to Brazilian ones, while at the time of visit (July) cotton and sugarcane crops were also free of *Acanthospermum*.

## Conclusions and Discussion

The foregoing survey partially covered the known distribution area of *A. hispidum* in South America and it will be seen that observations to date on possible insect or other controlling agents have been of a somewhat discouraging nature. The plant is regarded by competent botanical authority as native to

parts of Brazil, yet it is a noxious weed there, albeit an undeclared one, and it is in fact impressive that the heavy incidence occurs over a very wide range of edaphic and climatic conditions. In Brazil this abundance of the composite is noticeably concentrated on wasteland, tracks or roadsides, and certain types of cultivated areas. It is precisely under these same conditions, where the environment is subject to great modification by human agencies, that the weed finds its most favourable habitats in northern Nigeria. It is clear that in such habitats, at least in the sections of Brazil surveyed above, disease and insect controlling agents are very scarce and such as are present singularly ineffective. The position in northern Argentina is similar, although in the Tucuman area the problem of what causes the sporadic flower and fruit inhibition merits attention.

The relatively little time spent in survey in Venezuela and Colombia was sufficient to confirm the suspicion gained from literature that *A. hispidum* is rare in northern and northwestern South America. The reasons for this scarcity are not known, and no significance can be attached to the fact that the small numbers of plants examined in this region were free of insect and other attack until this absence is supported by further observations.

It will be noted that this low incidence of the weed in South America is found in areas of variable rainfall within latitudes 5° and 12°N. so that in some respects one may expect a good overall climatic approximation to the northern Nigerian environment where the composite reaches pest status. This is of recognized importance because of its bearing on synchronization of plant and insect life cycles etc. Wilson (1943, 1949) has suggested that the first work to be undertaken in attempting entomological control of a weed is a study of the climates of the invaded areas and the selection of homoclimes or climatic analogues of these within the natural distribution area of the weed. This principle was put forward after examination of evidence obtained in a study of *Hypericum perforatum* L. in France and Australia. Aside from its methodological validity it receives support from consideration of the four most successful cases of weed control to date, namely *Opuntia* spp. in Australia, *Clidemia* in Fiji, *Hypericum* in Australia and California, and *Cordia* in Mauritius. Comparison of the climates of the source areas of the effective phytophagous insects in these cases with the climates of the invaded countries, at least at the macroclimatic levels illustrated by the world classification systems of Koppen and Thornthwaite (in Haurwitz and Austin 1944, Trewartha 1954) shows close agreement of Trinidad with Fiji and Mauritius for *Clidemia* and *Cordia* insects; of Argentina and Uruguay with Queensland and New South Wales for *Opuntia* insects; and of Mediterranean countries with S. Australia and California for *Hypericum* insects. The application of comparative climatology to some phases of biological control work is now receiving greater emphasis; it is therefore worthwhile to include here a few remarks on the Nigerian and South American environments of *A. hispidum* from this aspect of the general problem.

Despite the fact that Africa and South America are "hot continents" with enormous territories situated in the tropical zone, the climate of northern Nigeria where *Acanthospermum* is a pest presents certain characteristics which appear to be difficult to approximate in Latin America (see Tables 1, 2, 3). Both continents have extensive belts of tropical savanna in the typical latitudinal location from about 5° to 20° on either side of the equator, and characterized by distinctive wet and dry seasons (Koppen's Aw type). However, N. Nigeria borders the Sahara, whereas nowhere in the low latitudes of South America does a desert of these dimensions occur. Furthermore, the tropical climates of the Latin continent are notorious for anomalies. With the proximity to the Sahara,

TABLE 2
Climatic Data.*  Calabozo, Venezuela

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Monthly Rainfall (Inches) | 0 | 0.2 | 0.3 | 2.8 | 6.7 | 7.4 | 9.1 | 8.6 | 7.2 | 5.1 | 3.3 | 0.6 | 51.3 |
| Mean Relative Humidity | 69 | 68 | 67 | 66 | 76 | 78 | 79 | 78 | 77 | 76 | 77 | 75 | 74 |
| Mean Monthly Temperature | 82.0 | 82.5 | 84.3 | 84.5 | 82.0 | 80.0 | 79.8 | 79.8 | 80.6 | 81.0 | 81.0 | 81.0 | 81.5 |

*From: Datos Detallados de Climatologia de Venezuela
Epifanio Gonzalez P.          Caracas 1948.

N. Nigerian temperatures are high and monthly and diurnal ranges large.   In the dry season the N.E. trade wind blows from the desert as the hot, dry, Harmattan to bring dust and very low humidities even as far south as the Guinea coast. These winds are of frequent occurrence at the end of the wet season and have well known effects on the vegetation.   Their influence would probably be equally critical for any insect populations attacking mature *A. hispidum* present at such times.

The foregoing climatic conditions are not really approached either in northeast Brazil or the llanos and Carribean coastal sections of Venezuela and Colombia, which are the two areas of South America most likely to reveal climatic analogues of the northern provinces of Nigeria.   In Brazil the dry interior section centred on the river Sao Francisco and inland from the wet coastal regions of Sao Salvador, Recife, etc. lacks the rhythmic temperature and rainfall patterns of Sokoto and other Nigerian localities.   Often the normally six months long dry season is not broken by rains and indeed this area of South America has the unhappy distinction of being one of the world localities of greatest rainfall unreliability.   *A. hispidum* is known to be common here at times, and any phytophagous insects attacking the plant would require unusual life cycles adapted to erratic appearances of their hosts.

Due to the mountainous terrain the Carribean littoral of Colombia and Venezuela shows considerable climatic diversity, whereas in the "llanos" the climate is more uniform.   Tables 2 and 3 give data for representative stations. In both coastal and interior areas the temperature pattern parallels that of the African environment in that the highest temperatures precede the rainy season, but monthly and diurnal ranges are very moderate relative to those of Northern Nigeria.   The rainfall regime in the arid coastal strip from the Guajira Peninsula to Cumana, Venezuela, shows a fair contrast between wet and dry seasons with a marked tendency to double maxima in the precipitation curves in the more western areas.   A rainless season from December to March is common in the llanos but although the skies are clear and the area under the influence of steady dry northeast trade winds, the relative humidity is quite high, and actually differs little from that on the littoral.   Thus there is in this part of South America nothing comparable to the Harmattan and the low humidities of Sokoto etc. These climatic differences might or might not be of importance in a programme of phytophagous insect introduction, and in any case there can be little doubt

TABLE 3
Climatic Data.* Maracaibo, Venezuela

|  | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Monthly Rainfall (Inches) | 0 | 0 | 0.3 | 0.8 | 2.7 | 2.2 | 1.8 | 2.2 | 2.8 | 5.9 | 3.4 | 0.6 | 22.7 |
| Mean Relative Humidity | 73 | 73 | 74 | 76 | 79 | 78 | 75 | 77 | 78 | 82 | 82 | 77 | 77 |
| Mean Monthly Temperature | 81.5 | 81.5 | 81.6 | 83.2 | 83.2 | 83.9 | 84.4 | 85.0 | 84.1 | 82.7 | 82.4 | 82.0 | 82.8 |

*From: Datos Detallados de Climatologia de Venezuela
Epifanio Gonzalez P.      Caracas 1948.

that the ecological conditions of the arid Carribean littoral are the best available South American counterparts of the N. Nigerian environment of *A. hispidum.*

The thesis that an insect control programme for a weed should be preceded by comparative climatological studies of the native and invaded areas with a view to selection of climatic analogues of the latter within the plant's natural range is a logical, and unquestionably, correct one. Its application in the present instance has met with unsuspected difficulty. *A. hispidum* has been shown above to occur in variable density over an enormous area of tropical South America, yet there are apparently no good "duplicates" of N. Nigerian climate within this extensive natural range of the plant, partly for the simple reason that there is no Sahara in South America. This is the more surprising since, at least among non-climatologists, it is usually taken for granted that tropical climates in general tend to uniformity throughout the world.*

The fact is that despite strenuous efforts by numerous climatologists to elaborate world patterns of similar climatic types in unconnected regions of the earth's surface, the bases of these types are of necessity so broadly defined as to obscure local differences and the essential uniqueness of climate at different points throughout the world. For these and other reasons some authors (e.g. Wolfe 1945) reject the application of standard meteorological data to ecological investigations and stress the need for microclimatic studies of habitats. This approach is scarcely practicable for the biological control worker interested in a comparison of two or more climates and their bearing on insect introductions to be made in a crop or weed usually scattered over wide expenses of territory. Meanwhile reliance must be placed on climate classification systems based on standard meteorological data, which at least have the advantage of availability throughout the world and thus define relative values.

The problem of the complex climatic patterns existing over the earth's surface and their possible limiting effects on the application of the biological control method is not yet fully acknowledged by workers in this field. But inclusion of trained climatologists in departments concerned with biological control programmes may eventually permit such analysis of the intentional worldwide movements of parasites, predators, etc. into different countries over the past half century as to provide a perhaps surprising measure of orientation in regard the acclimatization and naturalization of these groups.

*An assumption implicit in Taylor's recent claim (1955) that biological control methods can only be consistently successful in tropical islands. Climatic variability within these received scant recognition by Taylor, although such dissimilar islands as Bermuda and Hawaii were cited among examples of this favoured group.

*Summary*

The composite *Acanthospermum hispidum* D.C. has become a pest in certain sections of the northern provinces of Nigeria, West Africa. Following unsatisfactory results with chemical control an investigation was undertaken to determine its status in its native South American home and the possibilities of control by entomological means.

The plant is recorded from every country in South America except Chile. A survey there between March and August 1953 showed it to be abundant and a pest in wasteland, crops, etc. in many parts of Argentina and Brazil in habitats recalling those of N. Nigeria. In these two countries specific insect enemies were scarce and very ineffective over a wide range of edaphic and climatic conditions. Aphids such as *Macrosiphum* spp. and leafhoppers of the genus *Agallia* were dominant forms on the plants. There was a singular absence of leaf eating insect enemies and the occasional undetermined geometrid and coleopterous larvae collected were apparently casual or accidental feeders on the weed. No flower and seed enemies were found. In the Tucuman area of northern Argentina a pronounced inhibition of flower and seed production was observed in some stands of the plant but the cause could not be established.

In remarkable contrast with conditions south of the equator the incidence of *A. hispidum* in Venezuela and Colombia was very low. No insect or disease controlling agents were seen on the few plants located during a short survey of three weeks duration in this area. No obvious reason can be advanced for the scarcity of the weed here.

It is concluded that the possibilities of a control programme by entomological methods are very limited although the survey in northern South America was inadequate. Insect and other enemies of the weed appear to be few, and there is the difficulty of finding within the plant's natural range in South America ecological conditions which in climatic characteristics approach the invaded areas of northern Nigeria. The significance of climatic analogues in biological control work is briefly discussed.

## References

Bennett, C. W., and A. S. Costa. 1949. The Brazilian curly top of tomato and tobacco resembling N. American and Argentine curly top of sugar beet. *J. Agric. Res.* 78, 675-93.

Blake, S. F. 1921. Revision of the genus *Acanthospermum*. *U.S. Nat. Herb. Contrib.* XX, 383-92.

Costa, A. A. da. 1949. Plantas invasoras. *Serv. Inf. Agr. Min. da Agric.* Rio de Janeiro.

Haurwitz, B., and J. M. Austin. 1944. Climatology. McGraw-Hill, N.Y.

Herrera, F. L. 1939. Catalogo alfabetico de los nombres vulgares y cientificos de plantas que existen en el Peru. Lima.

Keay, R. W. J. 1949. An outline of Nigerian vegetation. Lagos.

Menezes, A. I. de. 1949. Flora da Bahia. Sao Paulo.

Molfino, J. F. 1945. Los abrojos de los campos Argentinos. *La Chacra* 15. 80-81.

Perez, E. A. 1936. Plantas utiles de Colombia. Bogota.

Perez, E. A. 1937. Plantas medicinales y venenosas de Colombia. Bogota.

Pittier, H. 1926. Manual de las plantas usuales de Venezuela. Caracas.

Pittier, H. 1939. Supplemento a la manual de las plantas usuales de Venezuela. Caracas.

Phillips, E. P. 1938. Two troublesome varieties of star-burs. *Farming in S. Africa.* July, p. 256.

Robledo, E. 1940. Lecciones de botanica (medical, industrial y agricola). Medellin.

Taylor, T H. C. 1955. Biological Control of Insect Pests. *Ann. App. Biol.* 42, 190-196.

Trewartha, G. 1954. An Introduction to Climate. McGraw-Hill, N.Y.

Uribe, J. A. 1941. Flora de Antioquia. Medellin.

White, C. T. 1941. Common Farm and Pasture Weeds. Pamphlet 87. Dept. Agric. Queensland.

Wilson, F. 1943. The entomological control of St. John's wort (*Hypericum perforatum* L.)
    *Bull. No. 169. Coun. Sci. Ind. Res.* Austr.
Wilson, F. 1949. The entomological control of weeds. In: The scientific bases of an inter-
    national biological control organization. *Int. Union Biol. Sci. Series B.* No. 5, pp. 53-64.
Wolfe, J. N. 1945. The use of Weather Bureau data in ecological studies. *Ohio J. Sci. 45,*
    1-12.

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# Notes on the Life History and Habits of a Chalcid, *Bruchophagus caraganae* (Nik.), (Hymenoptera: Chalcididae), Infesting Seeds of Caragana[1]

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## Introduction

In 1947, while a caragana breeding improvement program was being carried out on the Forest Nursery Station, Indian Head, Saskatchewan, it was discovered that a large percentage of seed was being destroyed by an insect. This insect, the caragana seed chalcid, which interfered seriously with the plant breeding work, is apparently identical with the Russian *Bruchophagus caraganae* (Nik.) (Nikol'skaya, 1952).

The chalcid occurs wherever caragana is grown in the Canadian Prairies, and destroys seeds of the Siberian pea-tree, *Caragana arborescens* Lam., as well as those of two less common species of caragana, the Russian pea-tree, *C. frutescens* DC., and pygmy caragana, *C. pygmaea* DC.

*C. arborescens* has proved over a period of 40 years to be the most valuable tree for general planting in the Canadian Prairies (Cram 1952), where it is used for field and home shelterbelts. It survives the extreme drought and temperature conditions better than any other cultivated tree used for windbreaks in the Canadian Prairies.

The seed was introduced from Russia by William Saunders in 1887 (Anonymous, 1939). In 1911, seedlings of this species of caragana constituted 1.5 per cent of the total number of broad-leaved trees distributed by the Forest Nursery Station (Cram, 1950). According to Mr. J. Walker, Superintendent, Forest Nursery Station, Indian Head, nearly six and one-half million broad-leaved trees were distributed in 1951, and of these more' than four million were caragana.

## Life History and Habits

The adult usually emerges during June and the first half of July through a small hole bored in the caragana seed coat.

By isolating caragana seed pods in cheesecloth bags and exposing them in groups for short periods during the summer it was found that oviposition occurred during the last three weeks in June and the first week in July.

Mating has occurred on the day of emergence and oviposition may take place the same day. Before ovipositing, the female selects a spot near the dorsal suture of the pod. It then inserts its ovipositor through the pod into the seed (Fig. 1), although an egg is not always deposited each time the ovipositor is inserted. One female inserted its ovipositor into a seed 45 times and examination of the seed showed that no eggs had been deposited. When infested seeds were examined it was found that usually there was only one egg per seed, although

in some cases, several were present. Seeds in which the cotyledons had just begun to form were preferred oviposition sites. Seeds which were punctured during oviposition were usually scarred near the micropyle (Fig. 2). Females were seen to feed on juices exuding from the oviposition wound when the ovipositor was withdrawn from the pod.
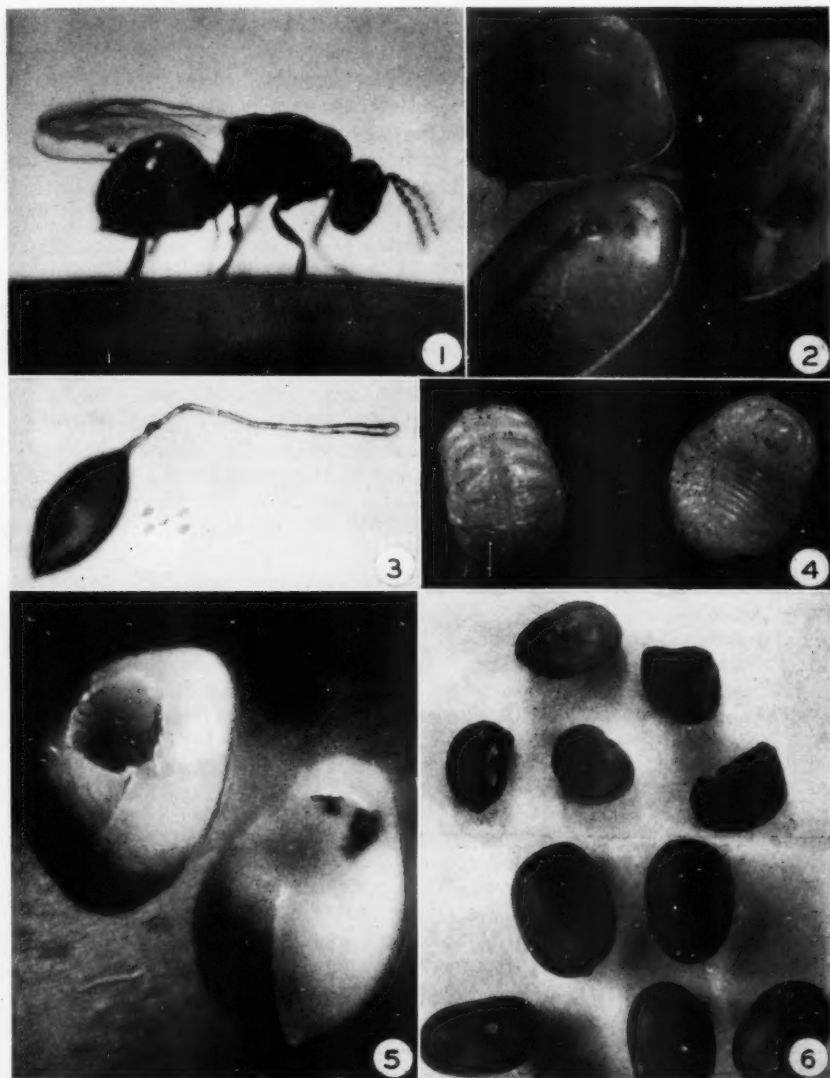


Figs. 1-6. *Bruchophagus caraganae* (Nik.). 1. Female chalcid ovipositing into caragana seed pod. 2. Immature caragana seeds showing oviposition scars. 3. Egg. 4. Larvae. 5. Damage to cotyledons of caragana seeds. 6. *Caragana arborescens* seeds, upper infested by *B. caraganae*, lower uninfested.

*Egg*

The egg is extremely delicate, almost colourless, oval in shape, and 0.28 mm. long with a very slender pedicel 0.57 mm. long (Fig. 3).

Data on the time required for hatching were obtained by daily examination of seeds for which oviposition dates were known. Seventeen infested seeds examined showed the minimum time to be seven days.

*Larva*

The larva is small, white, and legless, about 3.0 mm. long and 1.5 mm. wide when fully developed (Fig. 4). It has black, slightly curved mandibles.

The larval stage extends over a period of 11 months; in 1949, larvae were first observed on June 20, and in 1950, the earliest date on which pupae were observed was May 23. The entire period is spent within the seed.

Diapause has been observed to occur under laboratory conditions. Some larvae which were overwintered in 1949-50 did not pupate in the spring. They were kept in rearing the next year and in the spring of 1951, pupation and emergence took place.

The newly-hatched larva commences to feed on the tender growing cotyledons (Fig. 5) and continues until they are completely destroyed.

When more than one larva is present in a seed, competition results. Of 87 partly-grown larvae removed from seeds, 73 occurred singly, eight were in pairs and six were in threes, but only one fully-grown larva has been observed in a single seed.

After the larva has fed for a few days, the seed becomes discoloured, and a dark-brown patch appears on the seed coat immediately adjacent to the area in which the larva is feeding. When the pod reaches maturity the infested seed is hard but never smooth and plump, usually dull brown in colour. A mature uninfested seed is usually hard, smooth, and plump, and larger than an infested seed, (Fig. 6).

After passing the winter within the seed coat on the ground, the larva pupates.

*Pupal period*

To determine the duration of the pupal period, larvae were removed from infested seeds and placed individually in small gelatin capsules. Of 105 larvae in rearing only 34 emerged as adults. Pupation occurred during the period May 23 to June 19, 1950. The average duration of the stage for 23 males was 15.9 days; for females 17.0 days.

### Natural Mortality

Five species of parasites, *Amblymerus bruchophagi* (Gahan), *Habrocytus* sp., *Pachyneuron* sp., *Coelopisthia* sp. and *Eupelmella vesicularis* (Retz.) were reared from seeds infested with the caragana seed chalcid. *A. bruchophagi* (Peck, 1951; Trelease and Trelease, 1937), which is also a parasite of the clover seed chalcid, *Bruchophagus gibbus* (Boh.) was the most abundant; the other species were relatively scarce. *E. vesicularis* is a polyphagous parasite (Peck, 1951) for which the caragana seed chalcid is a new host.

In 1949, 26.7 per cent of the chalcids in *C. pygmaea* seed and 21.4 per cent in *C. frutescens* seed from Scott, Sask., were parasitized. Parasitism also occurred in infested *C. pygmaea* seed from Brandon, Man.

### Extent and Importance of Damage

Average infestation of *C. arborescens* by the caragana seed chalcid in samples collected in Manitoba, Saskatchewan, and Alberta was respectively 48.7, 25.1 and 27.1 per cent of 1949; in 1950 the figures were 32.0, 27.1 and 24.8 per cent

respectively. The most severe infestation recorded was 95 per cent of the seeds in a sample taken in Alberta in 1950.

A number of normal and infested seeds weighed separately at the time of dehiscence showed the average weight of the former to be 24.5 mgm. and the latter 10.9 mgm. Because of this difference in weight, normal and infested seeds can be easily separated with a fanning mill. For this reason the problem is not serious when seed is being produced for propagation. In breeding work, seed is produced in smaller quantities and losses, even though small, are of considerable importance.

### Acknowledgments

### References

Anonymous. 1939. Fifty years of Progress on Dominion Experimental Farms, 1886-1936. Canada Department of Agriculture, Ottawa, Ont.

Cram, W. H. 1950. Seminar on Caragana Improvement. Unpublished data.

———— 1952. Parent-seedling characteristics and relationships in *Caragana arborescens* Lam., *Sc. Ag.* 32: 380-402.

Nikol'skaya, M. N. 1952. Two new species of seed-eaters of the family Eurytomidae (Hymenoptera, Chalcidoidea) (In Russian). *Ent. Obozr.* 32: 304-306.

Peck, O. 1951. Superfamily Chalcidoidea. *In* Hymenoptera of America North of Mexico—synoptic catalog. U.S. Dept. Agric., Agric. Monogr. No. 2.

Trelease and Trelease. 1937. *Amblymerus bruchophagi* (Gahan). *Amer. Jour. Bot.* 24: 448.

# Ecology of the Leaf-cutter Bee *Megachile perihirta* Ckll. (Hymenoptera: Megachilidae) in Relation to Production of Alfalfa Seed[1]

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The relative importance as pollinators of alfalfa of each of the 14 species of *Megachile* that occur in southern Alberta has been assessed on the basis of Alberta distribution, frequency and abundance in mixed prairie, nesting habits, pollen preferences, and flight period; two ground-nesting species of the subgenus *Xanthosarus* Rob., *Megachile perihirta* Ckll. and *M. dentitarsus* Slad., were judged the principal pollinators (Hobbs and Lilly, 1954).

On range land (nesting habitat) separated from irrigated land (major food source) by the Bow River near Scandia, Alberta, lack of plants from which leaf-pieces could be cut to construct cells or from which whole leaves could be taken compelled *M. perihirta* to use an isolated chokecherry bush, *Prunus virginiana* L., as its leaf-cutting source, and provided the writer with the opportunity to study a population of this species. This paper supplements that part of the one by Hobbs and Lilly (1954) concerning the flight period and the nesting habits of *M. perihirta*. In addition, parasites and predators of this species are discussed, and the worth of the individual bee is assessed.

### Factors Influencing Flight Period

The method for determining the flight period was described by Hobbs and Lilly (1954). Table I shows the beginning, peak, and end of flight activity of

TABLE 1

Flight period of *M. perihirta* at Scandia, Alberta, 1950 to 1954

| Year | Beginning | Peak | End | Total days |
|------|-----------|------|-----|------------|
| 1950 | June 19 | June 29–July 7 | July 24 | 36 |
| 1951 | July  2 | July 17 | July 31 | 30 |
| 1952 | June 12 | July  2 | July 25 | 44 |
| 1953 | July  3 | – | July 28 | 26 |
| 1954 | July  5 | July 20 | July 28 | 24 |

*M. perihirta* for the years 1950 to 1954. Fig. 2 from Hobbs and Lilly (1954), the data of which are incorporated in Table I, is now interpreted differently because, if counts had been made during the nine-day period from June 29 to July 7, 1950, the peak might have been shown to be much higher; data for 1953 are also incomplete because no counts were made between July 9 and the end of the flight period. During the five years of observations, the beginning, the peak, and the end of the flight period varied by approximately three, two, and one week respectively; the earlier the date of emergence, the longer the flight period (Table I). Variations in date of emergence appeared to be related to the temperature prevailing during metamorphosis. The mean daily temperature from April 1 to June 12 was 7° and 9°F. lower in 1953 and 1954 respectively, when emergence was late, than in 1952, when it was earliest. Variations in length of flight period appeared to be closely related to temperatures prevailing during the flight period. The threshold temperature for flight activity as measured in the shade at the chokecherry bush was 65° to 67°F., and the bees worked almost continuously at or above this temperature until about one hour before sunset. During the long flight period of 1952, the number of hours between sunrise and sunset with temperatures at or above 65°F. were 260 as compared with 327 and 354 hours for the shorter periods in 1953 and 1954 respectively. Hence, when conditions remained favourable, the bee worked herself to death more quickly than when she was immobilized by periods of below 65°F. temperatures such as occurred between June 12 and 19 and again between June 21 and 26, 1952.

When the weather remained favourable throughout the flight period of *M. perihirta*, the total period was about 30 days (Table I, 1951, 1953, and 1954 data). If sufficient counts had been made each day at the bush, the curves would probably have closely resembled normal distribution curves, and the period during which about two-thirds of the population was working would have been about 20 days.

Hobbs and Lilly (1954) reported only one complete generation per year. Data for 1953 and 1954 support this conclusion. No emergence took place from the 15 complete nests excavated in 1953 until the cells had been chilled at 41°F. for 28 days, indicating a diapause at the prepupal stage. In 1954 a few new females were observed nest-building in September. Shortly after these observations were made, the weather turned cold and before it again became warm enough for flight activity all flowering growth had been killed by frost. Because bad weather accompanied by killing frosts sometimes occurs in early September in this region, the diapause appears to be necessary for survival of the species here.

### Nest Building

Hobbs and Lilly (1954) described the habitat of this species. All of more than 30 nests found since then were concealed beneath clumps of grass in sparsely

covered, gravelly areas or in areas of sandy loam where the vegetation was much more dense.

Hicks (1926) first described tunnel construction by *M. perihirta*. The writer has observed the excavation of several tunnels. In all but one instance, the bee began to dig in unbroken ground beneath a clump of grass. In the one instance, the female began enlarging an existing tunnel in a bare piece of ground lying between widely spaced clumps of grass. Tunnels often ended against small stones; sometimes they bent. The number of cells found in completed nests ranged from one to nine, the average being three.

Sladen (1918) stated that he found *M. perihirta* nesting gregariously in a nearly new and bare, gravel railway embankment at Cochrane, Ontario. Apparently the females establish their nests in the neighbourhood of the nests from which they have emerged. Almost without exception, whenever a nest was found by the writer, three or four others were found nearby. Tunnel entrances were often within two or three feet of each other within the groups, but large
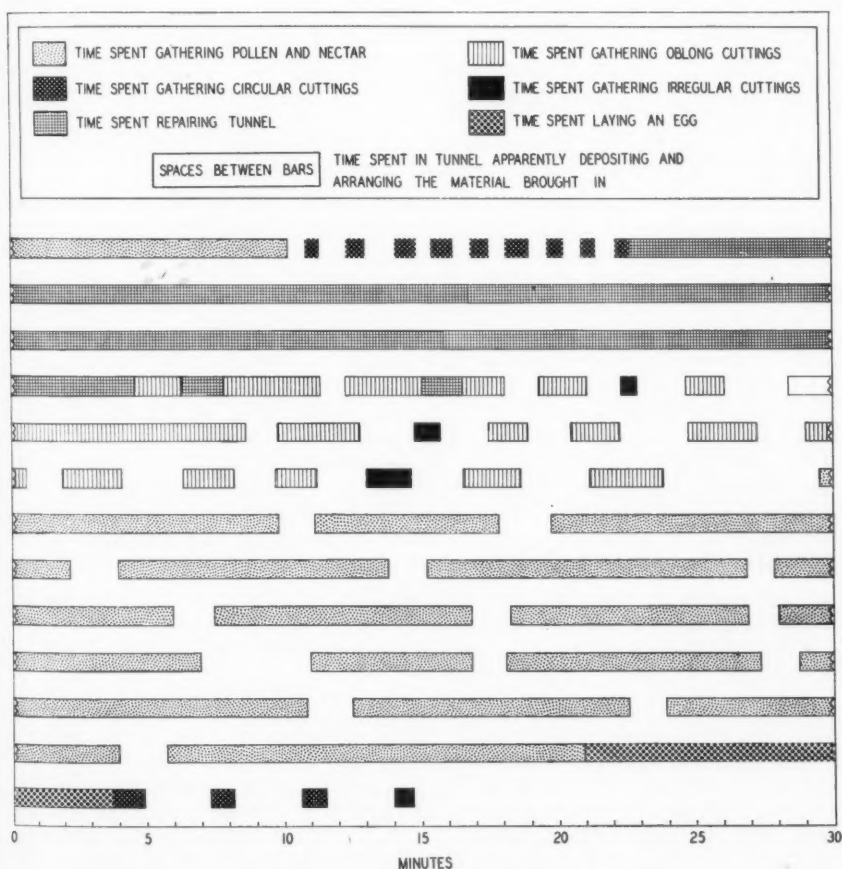


Fig. 1. Times required by *M. perihirta* for activities in constructing a cell, provisioning it, laying an egg, and capping the cell.

gaps of 25 yards or more, the cover of which was also typical nesting habitat, separated the groups of nests.

The construction and provisioning of a cell by each of two females was observed on the same day at approximately the same time. As the time spent in repairing tunnels and in constructing and provisioning cells, and the number of loads used for each task, were similar, data on only one are presented (Fig. 1). When the leaf-cutting source and food were abundant and close, about six working hours were required to repair the tunnel and construct, provision, and cap a cell. Some longer-than-average periods away from the nest (Fig. 1) were caused by the loss of leaf-cuttings during the return flight.

In areas lacking large-leaved species like choke-cherry, which has leaves broad enough to allow cuttings to be made without having to cut through the mid rib, trimmed whole leaves of prairie rose, *Rosa* spp., were used. The female usually began constructing a nest by bringing in a cutting of irregular shape to form the outer layer of the basal end of the cell. Then four or five uniform, oblong cuttings were arranged to form the outer walls; there was little overlap of the leafpieces in this outer layer. Another irregular piece was then used to patch the base. Three to five layers of oblong leaf-cuttings and irregular patches were placed to form the basal end and walls of the cell. Overlapping of oblong pieces became greater as the inside diameter of the cell was decreased by the addition of layers. The ratio of oblong to irregular cuttings was roughly four to one. When the leaf-cutting source was only 50 yards distant, the task of making the base and walls of the cell took about one and one-half hours (Fig. 1).

Fifteen loads of pollen were used to provision each of the two cells that were watched from commencement to completion. Approximately three hours (Fig. 1) were taken to gather pollen from nearLy golden aster, *Chrysopsis villosa* (Pursh.) Nutt. The time required to gather a load from a single-flower source like alfalfa is not known; it is probable that it takes considerably longer than from a multiflowered composite. It is probable that the pollen mass was moistened with honey after each food-collecting trip, for the mass was too moist to have been wetted at one time and no long, extra trips were made after the last load of pollen was deposited in the cell (Fig. 1). After laying an egg on the semi-liquid mass, the bee went back to the leaf-cutting source to cut the circular pieces with which she capped the cell; the average number of these was seven. The full length of the tunnel was never utilized for cell construction; after cell construction was completed, the remainder' of the tunnel was loosely packed with irregular cuttings and a portion of the threshold of excavated sand at the tunnel entrance was clawed back into the tunnel.

An average of one cell per day was completed by a bee that was first observed while excavating a tunnel and, five days later, was observed sealing it. This nest was built during a period when no work stoppage could have been attributed to bad weather.

Because *M. perihirta* does not construct all of its cells in one tunnel (Hobbs and Lilly, 1954), its biotic potential is difficult to assess. However, some measure of the cell-building potential may be gained from the length of the flight period and the number of cells completed in a day. As the total flight period does not exceed 30 days under favourable weather conditions (Table I, 1951, 1953, 1954 data) and the curve probably resembles a normal distribution curve, each bee probably works for 15 days, during which it may construct and provision about 15 cells. Fabre (1921) found that an average of 15 eggs were laid by each of several European species of solitary bees.

## Parasites and Predators

*Coelioxys rufitarsis rufitarsus* Sm. was found more often in cells of *M. perihirta* than any other parasite; 11 specimens were reared. Michener (1953) described egg laying and feeding of *C. octodentata* Say, a social parasite of *M. brevis* Say. The cells from which *C. rufitarsis* s. str. emerged had no outward signs of parasitization, indicating that this parasite lays its egg in the cell before it is capped, as does *C. octodentata*.

*Nemognatha lutea* Lec., a meloid parasite, emerged from two cells of *M. perihirta*. The adult beetles frequent the mauve flower-heads of thistles, *Cirsium* spp. Although the primary larvae (triungulins) were not found on these flowers, they may have ridden from flower to nest on the bee as do those of species of *Zonitis*, *Apalus*, and *Tricrania* (Balduf, 1935). A primary larva of *Tricrania stansburyi* (Hald.)[3] was found on a second-brood egg of *M. perihirta*, which was lying on the pollen-honey mass in the cell; both egg and larva were dead.

*Dasymutilla fulvohirta* (Cress.), a red velvet ant, emerged from four cells in which the larvae of *M. perihirta* had already spun their cocoons. The wingless females of this and other species of velvet ants were seen near tunnels of *M. perihirta*, apparently searching for them.

In two tunnels, cells were found with neat, round holes chewed through both cell wall and cocoon. The only sign of the original occupants of the cocoons were two head capsules of the larvae of *M. perihirta*. Eight of the nine cells in one tunnel had been despoiled in this manner, a single cell in the other. As the holes were much too small for the larvae to be removed *in toto*, and five dead ants, *Solenopsis molesta* (Say), were found among the remains of the cells, a group of these ants apparently entered the tunnel, chewed holes through cell walls and cocoons, and removed the mature larvae piece by piece. Hayes (1920) included grasshopper eggs among the insect hosts of this species. Grasshopper egg pods were often found near the cells of *M. perihirta*.

Although no adults of *M. perihirta* were seen in the grasp of a predator, the ambush of a female of *M. melanophaea melanophaea* Sm. on alfalfa by a crab spider, probably *Misumena* sp., was observed. A tiger beetle was seen to pounce on and destroy a ground-nesting andrenid, and the robber fly *Stenopogon inquinatus* Lw. was often seen attacking and killing honey bees while they gathered nectar from alfalfa. All of these predators are present in the areas where *M. perihirta* nests or gathers food, and, along with others, could be taking their toll of adults of *M. perihirta*.

### Synchronization of Blooming Period of Alfalfa with Flight Period of *M. perihirta*

Although the flight period of *M. perihirta* sometimes coincides with the blooming of alfalfa in southern Alberta, this is not always so. For example, an experimental field that was irrigated during the cold, dry spring of 1954 bloomed about 10 days before the bees emerged, and, before the flight had been underway for more than a week, the flowers had died or had been stripped from the rachises by hot, dry winds. These observations coupled with those on duration of flight period emphasize the need for synchronizing the period of maximum bloom with the activity of *M. perihirta*. The mean emergence date, June 24, lies more than a week away from all but one of the recorded emergence dates (Table I). However, the good weather usually encountered in July results in increased activity and the subsequent hastening of the end of adult life. As a result, the five flights ended within a week of each other (Table I). Hence, better advantage of the

3Determined by Dr. J. W. MacSwain, University of California, Berkeley, California.

pollinating services of this species might be taken by retarding growth by clipping so that blooming would begin about July 1, approximately 30 days before the date of end of flight. This lack of synchronization is thought to be an important factor in fluctuations of alfalfa seed yields in southern Alberta. Hobbs and Lilly (1954) concluded that competing growth was the most important reason for the loss of the services of pollinator species.

### Importance of *M. perihirta* in Production of Alfalfa Seed

The number of seeds set per flower tripped by various species of *Megachile* averaged five. The average number of seeds per pod for a 100-pod sample where *M. dentitarsus* was the principal pollinator was 6.3 with fiducial limits at the one per cent level of 5.8 to 6.9. A female of *M. perihirta* that was observed from the time it entered an alfalfa field until it flew back to its nest was seen to trip 372 blossoms.

A measure of the value of an individual bee in an alfalfa seed field can be estimated by multiplying the average values for seeds set per flower tripped (5) by flowers visited to obtain a load (372) by loads needed to provision a cell (15) by cells completed in a lifetime (15). Hence, one female of *M. perihirta*, given good weather, good luck in avoiding predators, and close and abundant supplies of food and leaves, might be responsible for setting 418,500 seeds, or about two pounds of alfalfa seed.

If a crop of 1,200 pounds of seed per acre were achieved in an area where this bee was the sole pollinator, and one-third of each working day were spent in gathering pollen and nectar from alfalfa, then a density of one female of *M. perihirta* per 24 square yards would be required during the 15 days of flying weather. If the crop were 200 pounds or less, as is usual in southern Alberta, the density would be only one per 144 square yards. When good weather prevails and adequate moisture is supplied, alfalfa fields remain in bloom for about five to six weeks. Where the later-emerging species, *M. dentitarsus* (Hobbs and Lilly, 1954), pollinates after the flight of *M. perihirta* ends, proportionately lower densities of both would be required to help achieve the above yields. Hence, it is no wonder that observers have failed to appreciate the services of this and other species of leaf-cutter bees.

### Summary

Because the time-temperature requirements are apparently less for the dvelopment of alfalfa than for the emergence of *M. perihirta*, in southern Alberta alfalfa often begins to bloom before the flight period of the bee begins. Therefore, the blooming of alfalfa must often be retarded to coincide with the flight period of the bee.

Daily activity of *M. perihirta* is limited to the period between sunrise and about one hour before sunset when the air temperature exceeds 64°F., and about one-third of each working day is spent in collecting pollen and nectar. Seasonal activity probably averages 15 working days, during which an average of one cell per day is completed.

The parasites *Coelioxys rufitarsis rufitarsis* Sm., *Nemognatha lutea* Lec., and *Dasymutilla fulvohirta* (Cress.) were reared from the cells of *M. perihirta*. The ant *Solenopsis molesta* (Say) is probably a predator.

Because a female of *M. perihirta* is responsible for an estimated production of about two pounds of alfalfa seed per season, so low densities of this species are required for adequate pollination that, even where good yields of alfalfa seed are achieved, few bees are seen. In the past, the failure to estimate their

densities on alfalfa fields and to recognize their individual worth resulted in lack of appreciation of the role of this and other species of *Megachile*.

### Acknowledgments

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### References

Balduf, W. V. 1935. The bionomics of entomophagous Coleoptera. *John S. Swift Co., St. Louis, Mo.*

Fabre, J.-H. 1921. Souvenirs entomologiques. Troisième série. Répartition des sexes. *Librairie Delagrave, Paris.*

Hayes, W. P. 1920. *Solenopsis molesta* Say (Hym.): A biological study. *Kansas Agr. Expt. Sta. Tech. Bull.* 20.

Hicks, C. H. 1926. Nesting habits and parasites of certain bees of Boulder County, Colorado. *Univ. Colorado Studies* 15: 217-252.

Hobbs, G. A., and C. E. Lilly. 1954. Ecology of species of *Megachile* Latreille in the mixed prairie region of southern Alberta with special reference to pollination of alfalfa. *Ecology* 35: 453-462.

Michener, C. D. 1953. The biology of a leafcutter bee (*Megachile brevis*) and its associates. *Univ. Kansas Sci. Bull.* 35: 1659-1748.

Sladen, F. W. L. 1918. Pollination of alfalfa by bees of the genus *Megachile*. Table of Canadian species of the *latimanus* group. *Canadian Ent.* 50: 301-304.

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# The Influence of Spray Programs on the Fauna of Apple Orchards in Nova Scotia. X. Supplement to VII. Effects on Some Beneficial Arthropods[1]

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The toxic effects of a number of orchard spray chemicals on predators and parasites were given in an earlier paper (MacPhee and Sanford, 1954), which presented results obtained before 1953 and gave a list of biotic control agents, their hosts, and periods of activity. It also gave a review of the literature, showing in tabular form the effects of orchard pesticides on beneficial species.

This paper gives additional data by including more chemicals and more predators and revisions of the data given in the earlier paper. The additional predators were the phytoseiid mites *Typhlodromus tiliae* Oudms. and *Phytoseius macropilis* (Banks) and the mirid *Deraeocoris nebulosus* (Uhl.). All three feed on phytophagous mites, and *D. nebulosus* is suspected of preying also on the larvae of both the eye-spotted bud moth, *Spilonota ocellana* (D. & S.), and the codling moth, *Carpocapsa pomonella* (L.), and on aphids.

The data given in Table I are based on small plots of apple trees, replicated three or more times at different localities. Each plot consisted of two to four trees treated either once or twice with the spray chemical at the concentration usually recommended in official spray calendars or by the manufacturer; the exception was DDT, the amounts used per 100 gallons of mixture being shown in the table.

TABLE I

Effects of spray chemicals on predator and parasite populations in Nova Scotia orchards, 1947-1955

| Predator(s) and Parasite(s) | Aramite¹ | Bordeaux | Captan | Chlorocide² | DDT, 2 lb. | DDT, ½ lb. | DDT, ¼ lb. | Erad³ | Ferbam | Fixed nicotine | Genite 923⁴ | Glyodin | Lead arsenate | Lime-sulphur | Malathion | Nicotine sulphate | Ovotran⁵ | Parathion | Perthane⁶ | Phygon⁷ | Puratized⁸ | Ryania, 100% | Summer oil | Synthetic cryolite | Wettable sulphur |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Acarina** | | | | | | | | | | | | | | | | | | | | | | | | | |
| Anystis agilis Banks | * | o | o | | ++ | ++ | ++ | o | o | o | | o | ++ | | ++ | o | o | ++ | ++ | o | | o | + | + | + |
| Hemisarcoptes malus (Shimer) | | o | | | + | | | o | o | | | o | o | + | | o | | ++ | | o | | | o | o | + |
| Mediolata novae-scotiae Nes. | + | o | o | | o | o | o | | + | +o | + | +o | o | ++ | + | o | o | + | | + | | o | | o | ++ |
| Phytoseius macropilis (Banks) | o | | o | | | + | + | | + | | + | | + | | | | + | | | | | o | | | ++ |
| Typhlodromus spp. | | o | +o | o | + | + | o | o | +o | + | + | o | o | + | ++ | + | +o | + | ++ | +o | | o | + | o | ++ |
| Typhlodromus tiliae Oudms. | o | | o | o | | + | o | o | o | | + | o | o | + | ++ | o | o | + | + | | o | o | | | ++ |
| **Miridae** | | | | | | | | | | | | | | | | | | | | | | | | | |
| Campylomma verbasci (Meyer) | | | | | +o | | | o | | | | o | | | | | o | ++ | | o | | | | | + |
| Criocoris saliens (Reuter) | o | | o | o | ++ | | + | o | o | +o | o | o | o | | ++ | + | o | ++ | ++ | + | o | ++ | | | o |
| Deraeocoris fasciolus Knight | | | | | ++ | | | o | | | | o | | | | o | | + | | o | | | | | |
| Deraeocoris nebulosus (Uhl.) | | | | | | | | | | | | | | + | | | | | | | | | | | |
| Diaphnidia pellucida Uhl. | | o | o | o | ++ | | o | o | o | o | o | o | o | | ++ | + | o | ++ | o | o | | o | o | o | o |
| Hyaliodes harti Knight | | o | o | | + | | | o | o | | | o | o | | ++ | o | o | ++ | | o | | | o | o | ++ |
| Pilophorus perplexus D. & S. | | | | | ++ | | | o | o | | | o | o | | ++ | + | | ++ | | o | | | o | o | ++ |
| Plagiognathus obscurus Uhl. | | | | | ++ | | | o | | | | o | +o | | ++ | o | | | | o | | | o | | +o |

TABLE I (*Continued*)

| Predator(s) and Parasite(s) \ Spray chemical | Aramite[1] | Bordeaux | Captan | Chlorocide[2] | DDT, 2 lb. | DDT, ⅔ lb. | DDT, ¼ lb. | Erad[3] | Ferbam | Fixed nicotine | Genite 923[4] | Glyodin | Lead arsenate | Lime-sulphur | Malathion | Nicotine sulphate | Ovotran[5] | Parathion | Perthane[6] | Phygon[7] | Puratized[8] | Ryania, 100% | Summer oil | Synthetic cryolite | Wettable sulphur |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Anthocoridae** *Anthocoris musculus* (Say) | + | — | O | + | + | O | O | — | O | O | + | O | O | — | ++ | + | O+ | — | ++ | O | — | + | O | — | O |
| **Thysanoptera** *Haplothrips faurei* Hood | O | O | O | O | ++ | ++ | + | O | O | +O | + | O | O | + | ++ | + | O | ++ | ++ | + | O | +O | + | — | + |
| *Leptothrips mali* (Fitch) | O | — | O | O | ++ | ++ | + | O | O | +O | + | O | O | — | + | + | O | ++ | ++ | O | — | O | +O | — | + |
| **Coccinellidae** *Stethorus punctum* (Lec.) | — | O | — | — | ++ | — | — | O | O | — | — | — | O | — | — | O | — | — | — | + | — | — | + | — | + |
| **Parasitic hymenoptera** *Agathis laticinctus* (Cress.) | — | O | — | — | — | — | — | — | O | — | — | O | ++ | — | — | — | — | — | — | — | — | O | — | — | O |
| *Aphytis mytilaspidis* (LeB.) | — | O | — | — | ++ | — | — | O | O | · | — | O | O | ++ | — | + | — | + | — | O | — | — | O | O | ++ |
| *Ascogaster quadridentata* Wesm. | — | O | — | — | — | — | — | — | O | — | — | O | ++ | — | — | — | — | — | — | — | — | — | — | — | — |
| *Euderus* spp. | — | O | — | — | — | — | — | — | O | — | — | — | ++ | — | — | — | — | — | — | — | — | — | — | — | — |
| *Scambus* spp. | — | O | — | — | + | — | — | — | O | — | — | — | + | — | — | — | — | — | — | — | — | — | — | — | — |
| *Trichogramma minutum* Riley | — | +O | — | — | ++ | — | — | — | — | — | — | — | +O | — | — | — | — | — | — | — | — | — | — | — | — |

*No information. —; no effect, O; reduction of numbers, O; practical elimination, +; possible reduction, evidence inconclusive, +O.

[1]2-chloroethyl-1-methyl-2-(*p-tert* butyl-phenoxy)ethyl sulphite (U.S. Rubber Co.).
[2]*p*-chlorobenzyl *p*-chlorophenyl sulphide (Boots Pure Drug Co.).
[3]10% phenylmercuric acetate (Green Cross Products).
[4]50% 2,4-dichlorophenyl ester benzene sulfonic acid (Gen. Chem. Div. of Allied Chem. & Dye Corp.).
[5]*p*-chlorophenyl-*p*-chlorobenzene sulphonate (The Dow Chemical Co.).
[6]1,1-dichloro-2,2-bis (*p*-ethylphenyl) ethane (Rohm and Haas).
[7]Dichloronaphthoquinone (U.S. Rubber Co.).
[8]11.5% phenyl mercuri moneothanol ammonium acetate (Gallowhur Chem. Corp.).

## Results and Discussion

The results summarized in Table I include much of the data in the earlier paper, together with the additional information gathered from 1953 to 1955. The table shows that malathion, parathion, sulphur, Perthane, and DDT have drastic effects on natural enemies. Nicotine sulphate, lead arsenate, summer oil, Ovotran, Phygon, ferbam, ryania, Genite 923, fixed nicotine, and Aramite are harmful to some species and innocuous to others. Bordeaux, captan, Chlorocide, Erad, glyodin, Puratized, and cryolite are relatively harmless to parasites and predators.

A number of the above materials may be used for specific control purposes without seriously interfering with a natural control program. The chemicals most widely used in Nova Scotia orchards include glyodin and captan for apple scab, and Ovotran, ryania, nicotine sulphate, and lead arsenate for arthropod pests.

## Acknowledgments

The authors are indebted to other officers of the Kentville laboratory: to Miss H. J. Herbert for identifying the phytoseiid mites and to Mr. H. T. Stultz for the data on the parasites of the eye-spotted bud moth.

## Reference

MacPhee, A. W., and K. H. Sanford. 1954. The influence of spray programs on the fauna of apple orchards in Nova Scotia. VII. Effects on some beneficial arthropods. *Canadian Ent.* 86: 128-135.

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# Notes on Beetles as Predators of Eggs of *Hylemya brassicae* (Bouché) (Diptera: Anthomyiidae)[1]

By George Wishart[2], J. F. Doane[3], and G. E. Maybee[4]
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Observations on predation of eggs of *Hylemya brassicae* (Bouché) were made from the Belleville laboratory from 1953 to 1955 as part of a general study of the biotic agents that act against the maggots that attack cruciferous crops. In biological control programs more attention has been given to parasites than to predators. Predation is more difficult to observe and to evaluate and, unlike parasitization, cannot be even roughly appraised by the collection and examination of hosts. As a group, predators are less specific in their food requirements and less regular in their habits than parasites and consequently do not lend themselves so readily to manipulation for biological control purposes. Predators used with success in biological control have had a high degree of specificity to their prey. Non-specific predators may, however, in the presence of large numbers of suitable hosts on which to feed, be important factors in reducing populations of noxious insects. Predation on eggs of *H. brassicae* is an example.

In the Belleville area, in spite of the large numbers of eggs of *H. brassicae* laid, larval populations are not high. There is a great disparity between the numbers of eggs laid and the resulting infestation, particularly in the second generation. Hot, dry summers undoubtedly influence hatching and establishment, but not all the summers in which observations were made were hot and dry and some other factor was obviously at work. The young larvae require relatively little time to enter the plant but the eggs, because of their exposed position and lack of motility, are particularly vulnerable to predators.

Several workers have made observations on predation of different stages of *H. brassicae*. Some of these assumed that the presence of large numbers of insects known to have predacious habits is evidence that they were feeding on the immature stages of *Hylemya* spp. Most of the references to predation on the eggs concern mites. Schoene (1916) suggested that predators destroy many eggs and mentioned that the mite *Trombidium sericeum* Say was very abundant around infested cabbage plants. Gillette (1888) stated that ". . . a species of *Trombidium*, did excellent service . . . by feeding greedily upon the eggs of *Anthomyia brassicae*". Gibson and Treherne (1916) reported a red mite as "predacious on the eggs but useless unless they [the mites] become more abundant". Several authors mentioned carabids and staphylinids as predators of the larvae but only Treherne (1916) gave data to show that they attack the eggs. His evidence was, however, obtained in the laboratory and, though it showed that these beetles are potential destroyers of eggs, there was no direct evidence that they were important in the field. Balduf (1935), in his comprehensive review of the bionomics of the entomophagous Coleoptera, did not cite any cases of predation by beetles on the eggs of *Hylemya* spp.

## Materials and Methods

The insects that preyed on the eggs were determined in two ways: by direct observation in the field and by testing in the laboratory the predatory capabilities of insects collected in the field. The relative abundance of the species was determined by the use of traps. Those used in 1953 were placed over the cabbage plants and were satisfactory except that some of the smaller species were kept from entering by a metal ramp that projected slightly above the soil. In 1954 and 1955 a simple "pitfall" trap was used. A six-inch glass funnel inserted into an ordinary glass jar was placed in the soil to its rim. The spout of the funnel led to a celluloid cylinder with a screen a short distance from the open bottom. This screen prevented the insects from drowning in any water that collected in the glass jar after rain. To collect the insects, the funnel was removed carefully without disturbing the soil, leaving the glass jar in place.

To obtain information on the movements of the beetles and their relative abundance in the cabbage patch and in other forms of ground cover, traps were placed among the cabbages and at distances of 25, 50, and 100 yards north, south, east, and west of the cabbage plot. Some of these traps were in growing buckwheat and some in wooded areas. All insects taken in these traps were counted, recorded, and released in the same area in which they were taken so that the population would not be reduced. The most important two predacious species were marked, when trapped or collected by other means, with different colours of aeroplane dope and released where caught so that subsequent trapping might reveal their movements.

Since the abundance of the various predators may vary throughout the summer, observations on predation of the eggs to be useful must be made at the time when the eggs are normally present. To avoid confusion with eggs laid naturally, these observations were made on eggs obtained in the laboratory and marked before being placed in the field. Staining with a solution of bengal rose at 16 mg./cc. in 10 per cent alcohol tinted the eggs so that they could be readily distinguished, did not impair their viability, and, as far as could be ascertained, did not alter their acceptability to the predators. Eggs laid in the laboratory and tinted in this manner were placed in groups of 10 in positions, similar to those of eggs laid normally, around cabbage plants chosen at random. As many units of 10 eggs were put out daily as the supply of eggs permitted. These were

left for 24, 48, and 72 hours, the last period being approximately the time the eggs require to hatch in warm weather.   At the end of each of these periods the remaining eggs were collected, counted, and checked for damage, and those that appeared undamaged were checked for viability.   Continuous records of ground and air temperature were made.

Observation of the various predators at work provided information that made it possible to determine the destroyed eggs as attacked by certain predators. Ground beetles usually devoured the eggs entirely but occasionally left pieces of the chorion after the liquid contents had been removed.   Staphylinid beetles pierced the eggs with their mandibles and, after sucking out the contents, left the chorion in a shapeless mass.   Practically no damage that could be attributed to mites was observed on eggs that were recovered after exposure, but mites in the laboratory pierced the chorion with their sharp chelicerae, causing a gaping hole but leaving the chorion more or less in the original shape.

*Bembidion quadrimaculatum oppositum* Say was the most important carabid attacking the eggs in the field.   To test its effect under controlled conditions a uniform number of eggs of *H. brassicae* were exposed to different numbers of adults of this carabid.   Cages of plastic screen were fitted with boxes measuring 7 by 7½ by 3½ inches that filled the bottom of each cage.   In each box was placed a small turnip buried in sand to approximately its mid section.   A total of 125 eggs of *H. brassicae* were placed around the turnip, some on the surface of the soil and some slightly below it, as would occur if they were laid naturally in the field.   In each of two replicates, the first cage was used as a check and five, 10, and 20 beetles were placed in cages two, three, and four respectively. When sufficient time had elapsed for the formation of puparia, the sand was sifted and the surviving hosts were counted.

### Results and Discussion

Carabids were by far the most important group of predators and staphylinids were of some importance also.   Table I indicates the predacious beetles encountered, their relative abundance, and their predatory capabilities as revealed by observation and laboratory tests.

Ants were very abundant, the most numerous species being *Lasius crypticus* Wilson.   Before the formal study on predation was undertaken, it was noted that ants were very abundant around some plants and scarce or almost absent around others but that this did not bear any relationship to the infestation by *H. brassicae*. The damage to plants where ants were plentiful was as great as where they were scarce or absent.   Careful observation produced no evidence that ants had any significance as predators of the eggs.   Mites, although they did attack eggs in the laboratory, were not present in sufficient numbers in the field to indicate that they were of any importance as predators.

*Bembidion quadrimaculatum oppositum* Say, the most abundant and also the most important predator, is a small species, 2.7 to 3.7 mm. long.   Most of the carabid beetles encountered were nocturnal but this species appeared to be diurnal.   According to Blatchley (1910), it is widely distributed in North America.   *B. nitidum* (Kby.) is a northern species and not so generally distributed or so abundant in the Belleville area as the former species.   *Aleochara bilineata* Gyll., as well as being a predator of eggs of *H. brassicae*, is the most important parasite, and is also predacious on the larval stages (Colhoun, 1953).

A total of 6,108 insects were captured in 20 traps in 1955.   Of these, 5,386 were Coleoptera, 3,485 being Carabidae.   Of the Carabidae, 189 were of *B. quadrimaculatum oppositum* and 154 of *B. nitidum*, the two most important

1956

TABLE I

Importance of Beetles Collected near Cabbage Plots as Predators of Eggs of *H. brassicae*

| Species | Egg-eating capacity* | Relative Abundance** |
|---|---|---|
| *Carabidae* | | |
| *Bembidion quadrimaculatum oppositum* Say.............. | PPP | AAA |
| *Bembidion nitidum* (Kby.)................................ | PP | AA |
| *Agonoderus lecontei* Chd............................... | PP | AA |
| *Tachyura incurva* (Say)............................... | P | A |
| *Agonum* sp........................................ | PPP | A |
| *Bembidion* sp........................................ | PP | A |
| *Geopinus incrassatus* (Dej.)............................ | O | A |
| *Harpalus caliginosus* (Fab.)............................ | O | AA |
| *Harpalus erraticus* Say................................ | O | AAA |
| *Harpalus pennsylvanicus* (Dej.) ...................... | O | AA |
| *Harpalus compar* Lec................................. | O | AA |
| *Harpalus viridiaeneus* Beauv........................... | O | AA |
| *Harpalus* spp........................................ | O | AA |
| *Feronia melanaria* (Ill.)............................... | O | AA |
| *Poecilus chalcites* (Say).............................. | O | A |
| *Poecilus lucublandus* (Say)............................ | O | A |
| *Triplectrus rusticus* (Say)............................. | O | A |
| *Bradytus latior* (Kby.)................................ | O | A |
| *Celia gibba* (Lec.).................................... | O | A |
| *Amara fallax* Lec..................................... | O | A |
| *Amara* sp........................................... | O | A |
| *Acupalpus carus* (Lec.)............................... | O | A |
| *Stenocellus rupestris* (Say)............................ | O | A |
| *Staphylinidae* | | |
| *Philonthus* spp....................................... | PPP | AA |
| *Aleochara bilineata* Gyll............................... | PPP | A |
| *Gyrohypnus hamatus* (Say)............................. | PP | A |
| *Oxytelus* sp......................................... | O | A |
| *Pseudolathra* sp...................................... | O | A |

*PPP—large; PP—intermediate; P—low; O—no evidence of predation on eggs.
**AAA—very abundant; AA—common; A—scarce.

TABLE II

Average Numbers of *Bemidion quadrimaculatum oppositum* and *B. nitidum*
Captured per Trap in Various Types of Ground Cover, 1955

| Ground Cover | B. quadrimaculatum oppositum | B. nitidum |
|---|---|---|
| Early cabbage............................... | 14.25 | 9.25 |
| Late cabbage............................... | 14.25 | 22.00* |
| Buckwheat.................................. | 14.75 | 5.5 |
| Deciduous trees (mostly poplar)............... | 4.33 | 1.33 |
| Coniferous trees (red pine)................... | .60 | .60 |

*A large portion of these were taken after egg-laying by *H. brassicae* had ceased.

predators.  Table II shows that the numbers of beetles taken in the traps were affected by the nature of the ground surface, as well as by the density of the population.  The insects could move more freely and consequently were more likely to enter the traps on smooth ground than on rough ground with debris. The beetles were much more abundant in cabbage and buckwheat than where there was forest cover.

TABLE III
Data on Exposure of Eggs of First and Second Generations of *H. brassicae to* Predators
for One to Three Periods at Two Localities, 1953–54

|  | Sydney Field Station | | | Prince Edward County | | |
|---|---|---|---|---|---|---|
|  | 24 hours | 48 hours | 72 hours | 24 hours | 48 hours | 72 hours |
| *First Generation, 1953* | | | | | | |
| Number of eggs exposed...... | | | | | | 990 |
| Number of eggs carried off or destroyed................ | | | | | | 478 |
| Number of recovered eggs that were viable............... | | | | | | 379 |
| *Second Generation, 1953* | | | | | | |
| Number of eggs exposed....... | 1590 | | 400 | | | 390 |
| Number of eggs carried off or destroyed.................. | 1074 | | 292 | | | 306 |
| Number of recovered eggs that were viable............... | 325 | | 67 | | | 54 |
| *First Generation, 1954* | | | | | | |
| Number of eggs exposed....... | 800 | 800 | 680 | 1000 | 800 | 680 |
| Number of eggs carried off or destroyed.................. | 162 | 450 | 442 | 464 | 419 | 412 |
| Number of recovered eggs that were viable............... | 225 | 129 | 103 | 330 | 244 | 189 |
| *Second Generation, 1954* | | | | | | |
| Number of eggs exposed....... | 1180 | 800 | 800 | 800 | 790 | 800 |
| Number of eggs carried off or destroyed.................. | 611 | 600 | 652 | 600 | 655 | 707 |
| Number of recovered eggs that were viable ............ | 342 | 113 | 91 | 59 | 64 | 43 |

Of 220 adults of *B. quadrimaculatum oppositum* and 238 of *B. nitidum* marked and released, only 12 of *B. quadrimaculatum oppositum* and 25 of *B. nitidum* were retaken in the traps. Their fewness is partially explained by the low relationship between the area covered by the traps and the total area. Moreover, tests showed that approximately 50 per cent of the beetles lost their markings in the first week and 85 per cent by the end of three weeks. Little useful information was, therefore, obtained about the movement of the beetles. Maximum movement, as shown by recovery of a marked beetle, was 49 yards. Nothing in the data or in the general observations indicated a general movement of either of the important species toward areas planted with cabbage, but other types of ground cover, e.g., buckwheat, appeared to be as favoured habitats as the cabbage plots. It is probable, therefore, that there is little or no specificity in the feeding habits of these beetles, at least in so far as root maggots are concerned.

The results of the field tests in which tinted eggs were exposed and examined after stated periods are shown in Table III. The data for 1954 are the more valuable because of the larger number of eggs used, the greater number of periods, and the general improvement in technique resulting from experience. A larger percentage of eggs was destroyed or carried off during the first 24 hours than during subsequent periods. This was, no doubt, due to the variation in availability of the eggs to the predators; most of the eggs that were easy to reach and probably those that were in clumps were taken during the first 24 hours. Often eggs close together or in clumps were all observed to be eaten. Eggs taken during later periods were probably less accessible or occurred singly and thus

required separate search or other random contact. If the predators are non-specific in their feeding habits their movements are apt to be random. Therefore a contact that yields several eggs reduces the host population more than where several contacts must be made for the same number of eggs.

In the cages in the laboratory the average percentages of eggs that developed to puparia after exposure to various numbers of the predator *B. quadrimaculatum oppositum* were: 0 beetles, 37.6; 5, 3.2; 10, 5.2; 20, 3.6. The number of predators showed little direct relation to the amount of reduction. Apparently five predators were capable of devouring all the eggs that were readily accessible in each cage during the time it took them to hatch, i.e., approximately three days.

An attempt was made to associate the average number of eggs missing with the mean temperature near the surface of the soil. Sufficient data were obtained for the second generation in the Belleville area to show that more eggs were taken when the temperature was between 20° and 23°C. than when it was lower or higher.

### Acknowledgment

The authors wish to thank Mr. W. J. Brown, Entomology Division, Ottawa, who identified the many specimens submitted during the investigations.

### Summary

Investigations at Belleville, Ontario, during three years showed that large numbers of eggs of *Hylemya brassicae* (Bouché) were destroyed by predacious beetles, especially *Bembidion quadrimaculatum oppositum* Say and *B. nitidum* (Kby.). There was no indication of specificity in the food requirements of these beetles and their abundance depended on the general type of ground cover rather than the presence of any particular form of food. No evidence was found that ants or mites were important as predators of the eggs.

### References

Balduf, W. V. 1935. The bionomics of entomophagous Coleoptera. Published by author.

Blatchley, W. S. 1910. The Coleoptera or beetles known to occur in Indiana. *The Nature Publishing Company, Indianapolis.*

Colhoun, E. H. 1953. Notes on the stages and biology of *Baryodma ontarionis* Casey (Coleoptera: Staphylinidae), a parasite of the cabbage maggot, *Hylemya brassicae* Bouché (Diptera: Anthomyiidae). *Canadian Ent.* 85: 1-8.

Gibson, A., and R. C. Treherne. 1916. The cabbage root maggot and its control in Canada. *Canada Dept. Agr. Bull.* 12.

Gillette, C. P. 1888. Parasites on *Danais archippus* and *Anthomyia raphani. Canadian Ent.* 20: 133-134.

Schoene, W. J. 1916. The cabbage maggot: its biology and control. *New York Agr. Expt. Sta. Bull.* 419.

Treherne, R. C. 1916. The cabbage maggot in British Columbia (*Phorbia brassicae*). The natural control by parasites and predacious insects. *46th Ann. Rept. Ent. Soc. Ontario,* 1915, pp. 140-145.

# Two Milky Diseases of Australian Scarabaeidae

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In view of the background of information on *Bacillus popilliae* Dutky (Beard, 1945) and the reported success of this bacterium in reducing populations of *Popillia japonica* Newm. (White and McCabe, 1950) and in view of the discovery of a similar bacterium attacking *Odontria* grubs in New Zealand (Dumbleton, 1945), a survey of microparasites and their possible pathogenicity in scarabaeid larvae was undertaken in Australia as a project supported by a Fulbright award.

Considering that a single season (May-December, 1953) was available for this study and the fact that in Australia hundreds of species of scarabaeids are known to exist, the larvae of which are difficult to identify, it seemed expedient to concentrate on three species which could be expected to occur in reasonably large numbers and which provided a sequence of larval activity throughout the period of study. The species chosen were *Sericesthis pruinosa* (Dalm.), *Aphodius howitti* Hope, and *Heteronychus sanctae-helenae* Blanch.

Several different bacteria, protozoa, and fungi were found to parasitize these three scarabaeid larvae, indicating a fertile area for further investigations. Of these diverse organisms two bacterial parasites of the milky disease complex were of especial interest. One of these was found in *Sericesthis* and the other in *Heteronychus*.

*Sericesthis* is found in coastal pastures of southeastern Australia and is a pest of lawn and cultivated turf in inland communities. It is active in the autumn months, third instar larvae being available for study from May until early August. *Heteronychus* also is a coastal species, doing its chief damage to maize crops as an adult. The larval ecology is not well known, but the larvae develop in the spring and early summer (November-December).

The *Sericesthis* milky disease was found in a heavy infestation of grubs in the lawn of the American embassy in Canberra, A.C.T. The *Heteronychus* disease was found in a lighter infestation of grubs in a corn field at Gerringong, New South Wales. In both cases the affected grubs, in advanced stages of infection, were uniformly chalky white in color, and blood drawn from them was opaque, being filled with bacterial spores. These symptoms were similar to those of *Popillia japonica* infected with *Bacillus popilliae* or *B. lentimorbus*. Seasonal conditions were responsible for differences in infection stages between the two organisms as observed in the field. Infected *Sericesthis* larvae, found in early June, contained only the spore stage of the bacterium. Apparently the infections had originated considerably earlier—probably when temperatures were higher and when the grubs were early in the third instar (possibly in March). On the other hand in *Heteronychus*, found in early December, some infected individuals contained mature spores and others contained vegetative stages of the same organism. Apparently at this time, transmission of the *Heteronychus* disease was actively in progress.

The milky diseases represent, insofar as is known at present, an unique host-parasite relationship in that the causal organism sporulates in the living host without causing obvious pathology. This constitutes a well-defined diagnostic character, but it also indicates a well-adapted parasite with low pathogenicity.

It is not clear from Dutky's (1940) original description of *B. popilliae* and *B. lentimorbus* whether "Type A milky disease" and "Type B milky disease"
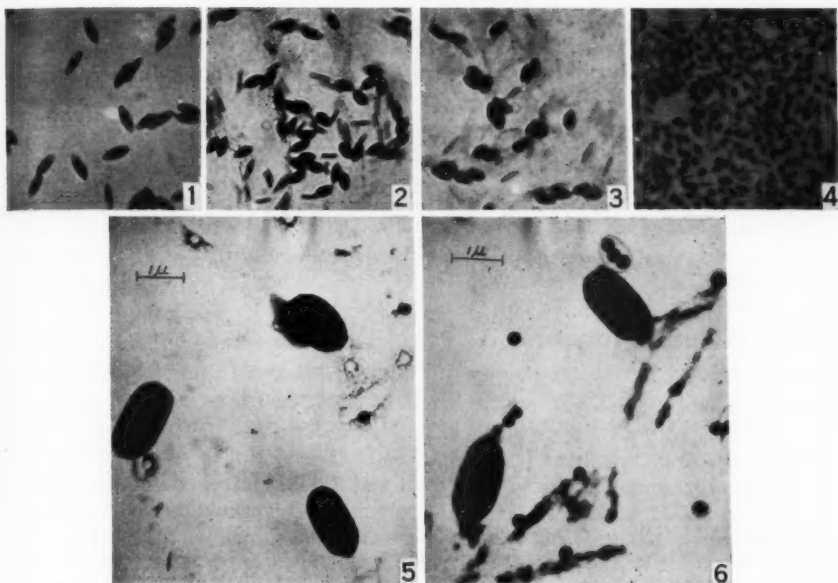
Figs. 1-4. Photomicrographs of spores at the same magnification, stained with Nile Blue Sulphate. 1, *Bacillus popilliae* Dutky; 2, *Bacillus lentimorbus* Dutky; 3, *Bacillus lentimorbus* var. *australis* var. nov.; 4, *Bacillus euloomarahae* sp. nov.

Figs. 5-6. Electron micrographs of:—5, *Bacillus lentimorbus* Dutky; Fig. 6, *Bacillus lentimorbus* var. *australis* var. nov. Prepared by V. A. Pickles, N.S.W. University of Technology.

are secondary designations of the causal organisms or are designations of the symptomatology of the two infections. If the former is the case, it seems unnecessary to add alphabetical alternates to names of the organisms, but a naming of new organisms is desirable. If the latter is the case, new infections doubtless can be fitted into the Type A or Type B categories, although this is not easy in view of the fact that the principal distinction is based on the appearance of larvae that have overwintered in the diseased condition. That this condition can occur at all again points to the low pathogenicity of the organisms, but it can be said that this represents the unusual rather than the usual situation. Neither *Sericesthis* nor *Heteronychus* was found infected as overwintering larvae, so their two bacteriemias cannot be catalogued as Type A or Type B disease on this basis of symptomatology.

*The Sericesthis milky disease organism*

The causal organism of the *Sericesthis* disease is a spore-forming rod-shaped bacterium. The spore stage (Figs. 3, 6) does not possess a refractile body as does *B. popilliae* (Fig. 1) or the organism causing the New Zealand milky disease. Thus it closely resembles *B. lentimorbus* (Figs. 2, 5) from which it cannot be distinguished by microscopic observations. Although in view of the probable geographical separation from *B. lentimorbus* and the differences in infectivity discussed below this disease might be considered to be caused by a new species of *Bacillus*, the similarity in appearance suggests that it is more practicable to consider the organism as a variety of *B. lentimorbus*. The name *Bacillus lentimorbus* var *australis* is proposed, and anticipating some observations and experiments discussed below, may be described as follows:

*Bacillus lentimorbus* var *australis*. n. var. (Figs. 3, 6)

From Australia, where organism was found.

Distinguished from *B. lentimorbus* by differences in infectivity among certain scarabaeid larvae.

Spores: Ellipsoidal, 0.9 by 1.9 microns, central or sub-central.

Sporangia: Swollen, spindle-shaped.   No refractile body present.

Rods: Unstained, about 0.4 by 4.0 microns.   Stained by crystal violet after fixing in Schaudinn's solution, 0.3 by 2.5 microns.   Non-motile.   Gram positive.

No growth on medium described by Steinkraus and Tashiro (1955) for growing *B. poppilliae*.[1]

Optimum temperature about 25°C.

Aerobic, facultative.

Source: Infected larvae.

Habitat: Causal organism of milky disease of *Sericesthis pruinosa*.

The similarity in appearance of *B. lentimorbus* and *B. lentimorbus* var. *australis* necessitated comparative studies to establish the similarity or dissimilarity of the two organisms.   Spores of *B. popillae* and *B. lentimorbus*, obtained through the kindness of Dr. S. R. Dutky, U.S. Department of Agriculture, were available for direct comparisons.   Even though the discovery of *B. lentimorbus* var. *australis* was made on the lawn of the American embassy in Canberra, no evidence was found that spores of *B. lentimorbus* had been imported into Australia and released, and *Sericesthis* has not previously been reported to be a host of *B. lentimorbus*.

Observations with the light and phase contrast microscopes disclosed no real differences between *B. lentimorbus* and *B. lentimorbus* var. *australis*.   Tendencies in the latter for the spore to develop more towards one end of the sporangium and to be somewhat more truncated were not consistent and could not be confirmed with the electron microscope.   V. A. Pickles of the N.S.W. University of Technology very kindly prepared, photographed, and measured the two varieties of *B. lentimorbus*, employing an R.C.A. EMC-2 console electron microscope.   *B. lentimorbus* spores (from the Dutky stock, obtained from *P. japonica* larvae) measured 1.63 ($\pm$0.05) $\mu$ in length and 0.81 ($\pm$0.04) $\mu$ in diameter.   The *B. lentimorbus* var. *australis* spores (from field-infected *Sericesthis* larvae) measured 1.88 ($\pm$0.06) $\mu$ in length and 0.90 ($\pm$0.03) $\mu$ in width.   It should be noted that the measurements for the typical species are somewhat less than those indicated in the original description.   The difference in spore size of the two varieties may not be important as the spores were derived from different hosts reared under different conditions, and they may not have been harvested at the same state of maturity.

*The Heteronychus milky disease organism*

The causal organism of the *Heteronychus* disease is distinctive and unlike the other milky disease organisms that have been described.   In size, the sporangium is conspicuously smaller than the other milky disease organisms.   The subspherical, eccentrically placed endospore seems to show considerable variation in size when stained with carbol fuchsin spore stain.   In view of the obvious differences between this and the other reported milky disease organisms, it is considered to be a new species.   The name of *Bacillus euloomarahae* is proposed, and may be described as follows:

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[1]Steinkraus (personal communication) has recently grown this organism on a somewhat modified medium, but subcultures did not grow satisfactorily.

*Bacillus euloomarahae* n. sp. (Fig. 4)

From euloomarah, aboriginal word for grub.

Spores: About 0.2 to 0.4 microns in diameter, subspherical, eccentric in transverse
axis, central in longitudinal axis.

Sporangia: Spindle-shaped.   No refractile body present.

Rods: Unstained, about 0.3 by 3.0 microns.   Stained by crystal violet after fixing
in Schaudinn's solution 0.25 by 1.7 microns.   Non-motile.   Gram positive.

No growth on medium described by Steinkraus and Tashiro (1955) for growing
*B. popilliae.*

Optimum temperature about 30°C.

Aerobic, facultative.

Source: Infected larvae.

Habitat: Causal organism of milky disease of *Heteronychus sanctae-helenae.*

*Infectivity and host relationships of the bacteria*

As with other milky diseases, infection of *B. lentimorbus* var. *australis* and
*B. euloomarahae* could be induced by inoculating spores into the body cavity
or into the alimentary tract of the appropriate host, the course of the diseases
paralleling remarkably well that of *B. popilliae* in larvae of *P. japonica.*

The infectivity of *B. lentimorbus* var. *australis* was not assessed adequately
because insufficient host material was available at any one time.   In a single test,
however, a parenteral inoculum of 15,000 spores per grub infected one out of
15 grubs (7 per cent) and an inoculum of 45,000 spores per grub infected four
out of 16 grubs (25 per cent).   These data indicate a relatively low degree of
infectivity, but they are within the range exhibited by the milky disease organisms
affecting the Japanese beetle larvae.

The more important biological differences in the bacteria appear in connec-
tion with infectivity in different species of scarabaeid host.   *B. euloomarahae*
evidently is infective in a wide range of hosts as it has been recovered from all
hosts so far inoculated.   These include *Heteronychus* (in which it was found),
*Sericesthis pruinosa, Popillia japonica, Anomala orientalis,* and *Autoserica castanea.*
It even developed, though in reduced numbers, in larvae of *Oryctes rhinoceros*
(in Western Samoa as reported in personal communication from R. A. Cumber,
to whom spore material was sent).   In this range of susceptible hosts, *B. euloo-
marahae* more closely resembles *B. popillia* than it does the other milky disease
organisms.

More striking differences in host susceptibility appear with *B. lentimorbus*
and its Australian variety.   It should be emphasized that host susceptibility must
be considered in relative rather than absolute terms.   Positive infection can be
interpreted unequivocally, but negative results may reflect too small an inoculum
(Beard, 1944), nonviable bacteria, or some other condition that at the time
precludes infection.   Suitable controls are not always possible.

Initial observations on *B. lentimorbus* and *B. lentimorbus* var. *australis*
inoculated into *Sericesthis* larvae suggested equal infectivity when this was judged
by the presence or absence of reproducing bacteria.   It was noted that, although
the blood of grubs infected with *B. lentimorbus* var. *australis* became typically
milky because of the large numbers of spores, this was not true of grubs infected
with *B. lentimorbus.*   These latter grubs never showed the external manifesta-
tions of the milky condition, although small numbers of spores could be seen
in the blood.

This observation led to a further test with mixtures of spores of these two
bacteria injected into *Sericesthis* grubs for a comparison with each of the bacteria

TABLE 1
Incidence of Infection

| Spore Inoculum | Total surviving grubs | Number showing rods | Number showing spores | Combined per cent infection |
|---|---|---|---|---|
| All *B. lentimorbus*............................ | 27 | 4 | 0 | 15 |
| 2 *B. lentimorbus:* 1 *B. lentimorbus* var. *australis*.... | 28 | 3 | 9 | 43 |
| All *B. lentimorbus* var. *australis*................ | 21 | 0 | 5 | 24 |

injected alone. Uniform suspensions, as determined by turbidity measurements, were made of the two bacteria. Mixtures of the two were prepared in such a manner that the total spore content was the same, but one contained two parts of *B. lentimorbus* and one part of *B. lentimorbus* var. *australis*, and another mixture contained one part of *B. lentimorbus* and two parts of *B. lentimorbus* var. *australis*. Uniform volumes of each of the mixtures and each of the pure suspensions were injected parenterally into *Sericesthis* grubs. These were held at room temperature for 17 days, and the incidence of infection and stage of disease development were then noted as in Table 1.

The most significant aspect of these data is that the grubs infected with *B. lentimorbus* alone showed bacteria only in the vegetative stage, and the grubs infected with *B. lentimorbus* var. *australis* alone showed bacteria in the spore stage. If the bacteria develop mutually exclusively as do *B. popilliae* and *B. lentimorbus* (Beard, 1946), and if the rod-spore distinction holds for the grubs inoculated with mixed cultures, it seems that *B. lentimorbus* var. *australis* is the stronger competitor. The high incidence of disease in the grubs receiving the mixture of one part *B. lentimorbus* to two parts *B. lentimorbus* var. *australis* might be interpreted to mean that the pattern of susceptibility in the *Sericesthis* population is different (negatively correlated) for each bacterium. Further tests involving far larger numbers of grubs would be required to test such a conjecture.

A subsequent repetition of this test yielded no significant information on the effect of mixtures because grubs inoculated with *B. lentimorbus* were not infected, and the mixtures induced infection in all test grubs, presumably as a result of the high infectivity of *B. lentimorbus* var. *australis*. Although the mixtures yielded no useful information, the response to the separate inoculations, which were made with serially diluted suspensions of pure spores, emphasizes the difference in host susceptibility. The original suspensions were prepared to contain the same number of spores, as measured turbidometrically. The actual number of spores was not estimated. These suspensions were serially diluted, and uniform volumes of each suspension were injected parenterally into *Sericesthis* grubs, which were held for five days and then examined. The presence or absence of infection, and not stage of infection, was noted as in Table 2.

The grubs inoculated with *B. lentimorbus* were not completely refractory, however, as ten days later five of the total 51 grubs then surviving were found to contain vegetative rods of the bacterium.

Further tests with larger numbers of grubs confirmed these results. When all the experimental data are viewed chronologically, a well-defined trend in host susceptibility appears. Early third instar larvae of *Sericesthis* seem to be equally susceptible to *B. lentimorbus* and *B. lentimorbus* var. *australis*, but whereas the latter goes through the customary cycle to form mature spores in large numbers, *B. lentimorbus* sporulates incompletely, few fully mature spores being formed.

TABLE 2
Incidence of Infection

| Inoculum dilution | B. lentimorbus | | B. lentimorbus var. australis | |
|---|---|---|---|---|
| | Grubs examined | No. showing infection | Grubs examined | No. showing infection |
| Original suspension = 1........ | 17 | 0 | 10 | 9 |
| 1/3.......................... | 11 | 0 | 12 | 12 |
| 1/9.......................... | 11 | 0 | 10 | 10 |
| 1/2.......................... | 9 | 0 | 10 | 6 |
| 1/81......................... | 9 | 0 | 12 | 3 |

As the host ages, it becomes much less susceptible to infection by *B. lentimorbus* and ceases to be a favorable medium for its growth. The older grubs, however, are fully susceptible to the Australian variety and continue to serve as a suitable medium for bacterial growth.

A difference in infectivity is also obvious between the bacteria injected into third instar larvae of *Aphodius* and of *Heteronychus*. Under conditions which cause infection in all test grubs with both *B. popilliae* and *B. lentimorbus* var. *australis*, no infection is induced by *B. lentimorbus*. Thus in three different tests, involving the injection of 66 *Aphodius* grubs with *B. lentimorbus* spores, no infection was evident in six days among the 36 grubs surviving at the time of examination. During this length of time infection by *B. popilliae* and *B. lentimorbus* var. *australis* was well established. Although fewer grubs were tested, *Heteronychus* larvae were susceptible to *B. lentimorbus* var. *australis* but not to *B. lentimorbus*. In these cases, lack of infectivity by *B. lentimorbus* was not due to loss of spore potency, as was demonstrated by subsequently inoculating *Popillia* larvae with the same spore material. Infection was promptly established, indicating the viability of the spores.

The susceptibility of several host species to the four milky disease organisms can be summarily tabulated in Table 3, with the understanding that the negative results seem to be characteristic but not necessarily definitive.

Various physiological strains of *B. popilliae* and *B. lentimorbus* have been indicated, (Tashiro and White, 1954) but the host relationships of these apparently have not been published.

TABLE 3
Susceptibility of scarabaeid larvae to milky disease organisms

| Larva | Bacillus popilliae | Bacillus lentimorbus | B. l. var. australis | Bacillus euloomarahae |
|---|---|---|---|---|
| *Sericesthis*................. | + | +early 3rd instar −late 3rd instar | + | + |
| *Aphodius*................... | + | − | + | not tested |
| *Heteronychus*............... | + | − | + | + |
| *Popillia*................... | + | + | + | + |
| *Anomala*................... | + | + | + | + |
| *Autoserica*................. | + | + | − | + |

*Pathogenicity of the milky diseases*

The pathology of the milky diseases is not clear. It is manifested by inhibited molting and metamorphosis and ultimate death of the affected individual, but the physiological changes responsible are not known. It was noted by Beard (1945) that blood of *Popillia* larvae infected with *B. popilliae* failed to melanize upon exposure to air, presumably as a result of diminished tyrosinase activity.

Blood from larvae of *Sericesthis* found in the field showing the advanced state of milky disease also showed this same phenomenon. On the other hand larvae becoming diseased in the laboratory as a result of inoculation of spores of *B. lentimorbus* var. *australis*, possessed blood which did melanize upon exposure to air. Although the melanization appeared to be somewhat less than that in blood from healthy grubs, this could not be stated with certainty as no reliable quantitative estimates of tyrosinase activity were made. This difference in response between field-collected and laboratory infected diseased grubs could possibly be explained on the supposition that the inhibitory action of the bacteria is reasonably weak, and whereas it is adequate to inhibit the tyrosinase when the latter is in relatively low concentration, it cannot inhibit the greater amount that is likely to be present in late third instar as pupation is approached. Field collected diseased grubs would have become infected as early third instar (or possibly late second), whereas the grubs used in the laboratory were late third instar. It is generally recognized that tyrosinase reaches its highest concentration in insect blood just before pupation.

Comparisons in this respect were not possible between *Sericesthis* grubs infected with *B. lentimorbus* var. *australis* and *B. lentimorbus* because the latter failed to develop sufficiently to cause the "milkiness" of blood to the extent that seems to be required.

Blood from *Aphodius* larvae infected with *B. lentimorbus* var. *australis* also melanizes about as rapidly but to a lesser degree than blood from healthy grubs. The grubs tested were also late third instar, when the tyrosinase content of the blood would be expected to be high.

It would appear that, although there seems to be some inhibitory action of *B. lentimorbus* var. *australis* toward tyrosinase in *Sericesthis* and *Aphodius* larval blood, the action is less definite than that of *B. popilliae* towards tyrosinase in *Popillia* blood. These observations suggest that the effects on melanization are not of great significance in these insects' pathology.

### Summary

In a search for pathogenic microorganisms in larvae of Australian Scarabaeidae, two bacteria, typical of the "milky disease" complex, were found. One bacterium found in *Sericesthis pruinosa* closely resembles *Bacillus lentimorbus*, but it shows marked differences in infectivity in different hosts so is considered to be a new variety. The other bacterium, found in *Heteronychus sanctae-helenae*, is distinctive in appearance and is considered to be a new species, infective in a wide range of scarabaeid hosts. Infectivity, host-relationships, and pathogenicity of these bacteria are discussed.

B. W. McFarland for assistance in the preparation of the other photographs. Comments of Dr. Edward Steinhaus are also sincerely appreciated.

### References

Beard, R. L. 1944. Susceptibility of Japanese beetle larvae to *Bacillus popilliae*. *Jour. Econ. Ent.* 37: 702-8.

Beard, R. L. 1945. Studies on the milky disease of Japanese beetle larvae. *Conn. Agric. Exp. Sta. Bull.* 491.

Beard, R. L. 1946. Competition between two entomogenous bacteria. *Science* 103: 371-2.

Dumbleton, L. J. 1945. Bacterial and nematode parasites of soil insects. *N.Z. Jour. Sci. and Tech.* 27: 76-81.

Dutky, S. R. 1940. Two new spore-forming bacteria causing milky diseases of Japanese beetle larvae. *Jour. Agric. Res.* 61: 57-68.

Steinkraus, K. H. and H. Tashiro. 1955. Production of milky-disease spores (*Bacillus popilliae* Dutky and *Bacillus lentimorbus* Dutky) on artificial media. *Science* 121: 873-4.

Tashiro, H. and R. T. White. 1954. Milky diseases of European chafer larvae. *Jour. Econ. Ent.* 47: 1087-92.

White, R. T. and P. J. McCabe. 1950. The effect of milky disease on Japanese beetle populations over a 10-year period. *B.E.P.Q. Pub.* E-801.

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# Holarctic Elements Among the Ichneumoninae of Canada

*By* Gerd H. Heinrich[1]

Dryden, Maine

The following records represent a supplement to my former publication "Holarctic Elements among the Ichneumoninae of Maine" (Jour. Wash. Acad. Science 43, May, 1953, p. 148-50). They are based mainly on material obtained by the Northern Insect Survey, which is a co-operative project of the Canada Department of Agriculture and the Defence Research Board, Canada Department of National Defence.

This contribution presents several species and two palaearctic genera not recorded before from America. I am indebted to Prof. H. K. Townes for sending me his material belonging to the mentioned two genera, thus enabling me to separate and describe a second Canadian species of one of these genera (*Hybophorellus* Schulz). I also have to thank Dr. W. R. M. Mason for his kind assistance in the preparation of this paper.

### *Trogus lapidator* F.

One male specimen of this species was reared by J. E. H. Martin from a pupa of *Papilio machaon*, the typical host of *T. lapidator* F. in the Palaearctic. The pupa was collected at Rampart House, Yukon Territory, Canada, July 15th, 1951.

This is the first record of the species from the New World and the first proof that a parasite of the subfamily Ichneumoninae Ashm. happened to follow its genuine host from one continent to the other.

### *Intermedichneumon calcatorius* Thunb.. ♀ ♂

Syn. *Ichneumon otiosus* Say ♀ 1829 (new Syn.)
*Ichneumon sylvanus* Hgn. ♀ 1880
*Ichneumon burkei* Viereck ♂ 1910 (new Syn.)

The Canadian National Collection contains 16 ♀ ♀ and 9 ♂ ♂ from Canada (Quebec, Ontario, New Brunswick and Nova Scotia), all reared from the

Liparidae *Hemerocampa antiqua* L. and *Hemerocampa leucostigma* A. & S. There are also 9 ♀ ♀ collected hibernating near Ithaca, N.Y.

Females of the series mentioned above belong to the species regarded in literature and collections as *I. otiosus* Say. They are also specifically identical with the specimens I recorded from Maine as *Coelich. calcatorius* Thunb.[1], which I had compared with a specimen of the latter species from European Alps.

W. R. M. Mason compared the male sex with the holotype of *I. burkei* Viereck and stated identity.

The generic position of this species is somewhat problematic as proves a glance into its literature where it changed between *Ichneumon, Cratichneumon, Stenichneumon* and *Coelichneumon*. H. Townes placed *otiosus* Say into *Coelichneumon* Thoms. as I did loc. cit. with *calcatorius* Thunb. However, this placement is only partially satisfactory. The propodeum of *calcatorius* Thunb. is not so much rounded downwards as it should be in a true *Coelichneumon*-species, and its aerolation is of a peculiar type. There is a biological character also differing from *Coelichneumon*: the series collected at Ithaca, N.Y., proves that this species hibernates. None of the true *Coelichneumon* do.

It seems to me that the species fits quite easily into *Intermedichneumon* Heinr. erected originally for some oriental species as a subgenus of *Melanichneumon* with deep gastrocoeli like *Coelichneumon*, non-punctured postpetiole and somewhat convex scutellum. (Cf. Mitt. Zool. Mus. Berlin, 1934, p. 194 and 207).

### *Ichneumon computatorius* Müll
### *nearctivernus* ssp. nov. ♀

*Type Locality*:—Smoky Falls, Matagami River, Northern Ontario, Canada.
*Holotype*:—♀, G. S. Walley, 12.VI.1934, C.N.C. No. 6408.
*Paratypes*:—3 ♀ ♀, Smoky Falls, Ontario, G. S. Walley, 13.VI. and 5.VII.1935; 1 ♀, Norman Wells, Northwest Territories, C. D. Bird, 19.V.53; 1 ♀, Mt. Murray, Alberta, G. E. Pall, 3.VII.53; 1 ♀, Rampart House, Yukon Territory, J. E. H. Martin, 29.V.51; 1 ♀, Christopher Lake, Sask., A. R. Brooks, 3.VII.39; 1 ♀, Fairbanks, Alaska, W. R. M. Mason, 25.VI.52; in the Canadian National Collection. 2 ♀ ♀, Dryden, Maine, U.S.A., G. H. Heinrich, in collection of Gerd H. Heinrich.

The species *computatorius* Müll. is uniquely characterized among all others of the genus Ichneumon of the Palaearctic by morphology of flagellum. The latter is short, extremely broadened and extraordinarily flattened beneath beyond middle and then attenuated, the first joint being less than twice as long as wide at the apex, the broadest about three times broader than long.

The colour of the species is black including legs, with white marks on sixth and seventh tergite and reddish inner orbits.

The North American specimens agree exactly with series from Germany in colour as well as in morphology. They are constantly different, however, in sculpture of coxae III, which are glossy with few, scattered punctures and no scopula, while the coxae III of palaearctic specimens are densely punctured and have a distinct scopula. Considering the identical structure of both series in every other regard, I can evaluate the difference in sculpture of coxae as a subspecifical character only.

### *Aoplus ruficeps* Grav. ♀

This species is uniquely characterized by the short, extremely stout antennae which are absolutely filiform, tapering slightly towards the base but not a bit at the apex.

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[1]Journ. Washingt. Acad. Sciences 43, No. 5, 1953, p. 148.

Among known American species of the genus only *A. velox* Cress has a rather strong and stout flagellum though not nearly as stout as *ruficeps* Grav. Both species may easily be distinguished by difference in relative length of first joint of flagellum, which is 1.75 times longer than wide at the apex in *ruficeps* Grav., 2.30 times longer in *velox* Cress.

European specimens of the species are mainly red, often mutating to some black and always with a whitish mark on the seventh tergite.

All 5 American specimens I have seen are red except a black flagellum with white annulus, a yellowish end of scutellum and seventh tergite and usually some more or less extended dark marks of propleura, mesopleura and mesosternum. This coloration fits into the scheme of mutation of European populations.

Recorded as follows: 1 ♀, Dryden, Maine, G. H. Heinrich; 1 ♀, Merivale, Ontario, J. J. de Gryse; 1 ♀, Gracefield, Quebec, O. Peck; 1 ♀, Jacquet River, New Brunswick, G. S. Walley; 1 ♀, Shediac, New Brunswick, G. S. Walley.

### Genus *Hybophorellus* Schulz

This genus was till now known only from Europe and not recorded before from the New World. It is a distinct genus easily recognized by the following characters:

♀ ♂

Clypeus convex as in the *Platylabini*. Mandibles strongly narrowed with small, nearly even teeth. Temples broad. Mesonotum and scutellum strongly convex, the latter considerably elevated above postscutellum. Propodeum fairly short with blunt, short apophyses (sometimes rather indistinct). Postpetiole irregularly, sometimes indistinctly, reticulated coriaceous. Gastrocoeli small and shallow.

#### Female

Apex of abdomen amblypygous, the hypopygium without bristles. Flagellum attenuated.

#### Male

Thyloides very broad, short oval to almost circular, occupying the basal part of joints of flagellum.

The morphology of the head of this genus reminds one of the *Platylabini*, the characters of the flagellum of both sexes, however, exclude the possibility of placing it into this tribe. To me it seems to be a link between the *Ichneumonini* and the *Hoplismenus* group. Nothing is known about the hosts.

Two North American forms will be described below, one considered to be a subspecies of a palaearctic species, the other to be a new species. A single male from Baffin Island evidently belongs to a third form which, however, cannot be identified and placed before further material is available.

#### Key for the American *Hybophorellus* species

♀ ♂

1. Cheeks obliquely striated. (Flagellum of female considerably broadened beyond middle. Abdomen red and black) _____ *injucundus* Wesm.
   *nearcticus* ssp. nov. ♀ ♂
   (Northwest Territories)
   Cheeks not striated _____ 2
2. Abdomen and mesonotum red (Flagellum of female not broadened beyond middle)
   *townesi* sp. nov. ♀ ♂ (Saskatchewan)
   Whole body including flagellum black, except legs which are vivid red. Thyloides white _____ single ♂ specimen (Baffin Island)

### *Hybophorellus townesi* spec. nov. ♀ ♂

*Type Locality*:—Secretan, Saskatchewan, Canada.
*Holotype*:— ♀, J. G. Rempel, 15.VII.44, in collection H. Townes.

*Allotype*:— ♂ , Swift Current, Sask., Canada, R. H. Sparrow, 21.VI.37, in collec-
tion H. Townes.
*Paratype*:— ♀ , (Locality and dates as in holotype), in collection G. Heinrich,
Dryden, Maine.

This species differs from *H. injucundus nearcticus* Heinr. distinctly by the
non-striated cheeks, the much more slender flagellum, the less pronounced teeth
of propodeum, which are only slightly indicated, and the narrower cheeks.

### Female

Red.  Lower margin of metapleurae narrowly and a middle stripe of meso-
sternum blackish.  Flagellum somewhat infuscated towards apex.  Length: 10
mm.

### Male

Black colour more extended than in female.  Black are: whole propodeum,
pleura, sterna, greatest part of coxae, trochanters, face except middle field, clypeus,
frons including ocellar field but excluding inner orbits, cheeks, base of mandibles,
and flagellum above in the basal part.  Length: 12 mm.

### Female

Head transverse.  Temples broad, their profile hardly narrowed behind
eyes.  Temples and occiput roundly and not abruptly sloping behind eyes and
ocelli.  Occiput deeply and almost angularly emarginated behind.  Cheek profile
strongly and in nearly straight line narrowed towards mandible base.  Middle
field of face strongly elevated, clypeus distinctly separated by a transverse
depression, convex, with oblique angles.

Mandibles narrow, the upper tooth but a little longer than the lower.

Flagellum long, slender, very strongly attenuated, not broadened but flattened
below beyond middle, with 42 joints, the first joint 2.35 times longer than wide
at the apex, about the tenth joint seen from the side as long as wide, the broadest
seen from the flat side hardly as long as broad, reddish, somewhat infuscated
towards the apex.

Mesonotum distinctly longer than wide, strongly convex, almost without
indication of notaulices.  Scutellum strongly convex and elevated above post-
scutellum, roundly sloping down to the latter, shiny with scattered fine punctures.

Propodeum densely reticulate punctured with feeble areolation.  Costulae
obsolete or almost so.  Area superomedia transverse, front angles rounded.  Hind
edges of areae dentiparae shortly and bluntly projecting.  Metapleura transversely
striated.

Postpetiole with indistinctly limited middle field, finely and irregularly
reticulated, smoother toward the end.

Gastrocoeli hardly impressed.

Coxae III finely and fairly densely punctured all over.

#### *Hybophorellus injucundus* Wesm.
#### *nearcticus* ssp. nov. ♀ ♂

*Type Locality*:—Bernard Harbour, Northwest Territories, Canada.
*Holotype*:— ♀ , Canad. Arct. Exped., 12.VII.1915, C.N.C. No. 6409.
*Allotype*:— ♂ , Chesterfield, Northwest Territories, J. R. Vockeroth, I.VIII.1950,
in Canadian National Collection, Ottawa.

Until now this species was known only from Europe: England, Sweden and
Germany (Thüringen).  Several years ago I recorded it from different high
mountain tops of the Bavarian Alps where it had been collected at altitudes of
about 6000 feet.

The nearctic specimens agree with the alpine in all essential morphological characters and especially in the unique obliquely striated sculpture of cheeks. The area superomedia is, however, considerably larger and broader compared with the alpine specimens, the carinae of propodeum are less distinct and elevated, and the costulae absent. The flagellum of the female is a little more broadened, the broadest joint seen from the flat side being 1.8 times wider than long in the nearctic female, only 1.55 times wider in alpine specimens.

### Female

Red colour more extended than in the palaearctic subspecies, covering in the holotype the whole mesonotum, scutellum, surface of propodeum, mesopleura, mesosternum, coxae I and II, upper and lower third of pronotum, occiput and sides of face and frons. Antennae and abdomen as in the nominate subspecies: the former black with white semi-annulus, the latter with tergites 1-3 and sides of 4 red, the rest black.

### Male

The allotype differs from alpine males by the red colour of mesonotum, scutellum and postscutellum, the rest of the thorax being black as in the nominate form. The flagellum is black with the short oval thyloides being yellowish and showing up strikingly from the dark ground colour. Femora, tibiae and tarsi red, only basal half of femora III black. Otherwise coloured like the alpine specimens, the head and tergites 4-7 being black, tergites 1-3 almost entirely red.

### *Ctenamblyteles homocerus* Wesm. ♀ ♂

The genus *Ctenamblyteles* Heinr., based on this species, is closely related to *Patroclus* Cress. It differs from the latter by the strong and regular, long pectination of the whole length of shafts of all claws. It seems not yet to be recorded from the American Continent.

The species *homocerus* Wesm. turns out to be widespread over North America with a boreo-alpine distribution transcontinental in the North from Alaska to Quebec and also occurring in the mountains of Colorado and Wyoming. I examined 8 specimens from 6 Canadian and Alaskan localities in the Canadian National Collection and 3 specimens from Steamboat Springs, Colorado collected by H. Townes. I compared them with a series of European specimens from the Bavarian Alps, and found all to be identical except that the population from Colorado has slightly darker wings. One ♂ from G. Teton Nat. Park, Wyoming in the collection of H. Townes has the 2nd and 3rd tergites red.

The species was found at the following localities in North America: 1 ♂, Anchorage, Alaska, R. S. Bigelow, 11.VII.51; 1 ♀, Ft. Nelson, British Columbia, W. R. M. Mason, 13.VI.48; 1 ♀, Salmita Mines, Northwest Territories, J. G. Chillcott, 22.VI.53; 1 ♀, Coppermine, Northwest Territories, S. D. Hicks, 2.VII.51; 1 ♂, Rupert House, Quebec, D. P. Gray, 7.VIII.49; 1 ♂, Rampart House, Yukon Territory, J. E. H. Martin, 11.VII.51; 2 ♀ ♀, Macdiarmid, Lake Nipigon, Ontario, N. K. Bigelow, 7.VI.21, 25.VI.23; 3 ♂ ♂, 1 ♀, Steamboat Springs, Colorado, H. M. S. D. & J. Townes, 6.VIII.48; 1 ♂, S. Teton Nat. Park, Wyoming, D. T. & J. N. Knull, 14.VII.39.

### *Ectopius exhortator* Thunb.
#### ssp. *thoracicus* Cress ♂ ♀ (new comb.)

### Female
(Description based on 4 specimens from Ontario, Canada)

Agrees in colour with the male except that the flagellum is tricoloured: red in the basal third, black at the end with a broad white annulus in the middle.

Ssp. *thoracicus* Cress. agrees with the palaearctic nominate subspecies in all essential characters of morphology and colour.   It differs as follows:

### Female

Black colour includes the mesonotum which is almost always red in European specimens.

### Male

Black colour in average of 25 specimens from Ontario, Canada, less extended than in males of the nominate subspecies: Coxae constantly red (usually partially black in European specimens), mesosternum and mesopleura black only in 4 specimens, while these parts in the nominate subspecies are black as a rule.

(Received September 16, 1956)

# Note on *Paranthrene tabaniformis* Rott., a Moth New to North America (Lepidoptera: Aegeriidae)[1]

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In July, 1952, at Mount Pearl, Newfoundland, larvae were found boring into the trunk of an injured balsam poplar, *Populus balsamifera* L.   In June, 1953, six moths emerged from sections of the injured trunk placed in a cage in an insectary.

Dr. T. N. Freeman (in litt.), Entomology Division, Ottawa, who determined the moth as *Pyranthrene tabaniformis* Rott. (*vespiformis* Westwood), stated that this was probably the first record of this European species in North America. This was confirmed by Mr. Kelvin Dorward (in litt.), Economic Insect Survey Section, United States Department of Agriculture, Washington, D.C.

The following distribution of *P. tabaniformis* is given by Seitz (1913): most of Europe and southeast to Asia Minor, and Transcaucasia.   It is considered a rare species in England (South, 1939).

*P. tabaniformis* is occasionally of some importance as a pest of poplars in some European countries.   It has been recorded on *Populus nigra* L. and *P. tremula* Michx. by Seitz (1913).   According to Seitz (1933) the larva bores in swellings on twigs and branches of poplar, also in the bigger roots of young trees, in stumps of cut branches, and at the base of the trunk.

A common name for *P. tabaniformis* is not given in the list of approved names of the Association of Applied Biologists (1952), but South (1939) calls it a clear underwing and gives as an alternative name a dusky clearwing.

### Acknowledgment

### References

Association of Applied Biologists. 1952.  Common names of British insects and other pests. Part Two.
Seitz, A. 1913.  Die Gross-schmetterlinge der Erde. Vol. 2.  Alfred Kernen, Stuttgart, Germany.
Seitz, A. 1933.  Die Gross-schmetterlinge der Erde. Supplement to Vol. 2.  Alfred Kernen, Stuttgart, Germany.
South, R. 1939.  The moths of the British Isles.  2nd ser. Warne, London.

# Chemical Control of the Pine Needle Scale, *Phenacaspis pinifoliae* (Fitch) (Homoptera: Diaspididae), in British Columbia[1]

*By* M. D. PROVERBS[2]

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During the past few years the pine needle scale, *Phenacaspis pinifoliae* (Fitch), has severely injured ponderosa pine, Engelmann spruce, and other evergreens in the Okanagan Valley of British Columbia. The home owner is most concerned because this insect is capable of ruining the appearance of evergreens on his property. Infestations may be severe on trees growing in submarginal forest areas.

Field experiments were conducted in the South Okanagan Valley in 1955 to determine whether lime-sulphur, malathion, or Diazinon (0,0-diethyl-0-[2-isopropyl-4-methyl-pyrimidyl (6)] thiophosphate) would control the scale on ponderosa pine trees.

## Materials and Methods

In the first experiment, ponderosa pine trees were sprayed to the point of drip with a hand-gun orchard sprayer at a pressure of 450 to 500 pounds per square inch. The trees, 20 to 30 feet tall, were severely infested with the scale. Malathion, Diazinon, and lime-sulphur were each applied to four or five trees on July 11, when about 75 per cent of the overwintered scale eggs had hatched. The malathion- and Diazinon-sprayed trees were treated again in mid August, when hatching was completed. Other trees were sprayed in mid August for the first time with malathion, Diazinon, or lime-sulphur. Scale mortalities were recorded on September 12.

In the second experiment, the sprays were applied with a turbine-type of concentrate sprayer commonly used in the Okanagan tree-fruit orchards. The sprayer was drawn very slowly, and in some instances stopped momentarily under the trees to permit the spray to attain maximum height. The pine trees were thoroughly covered with insecticide but not to the point of drip. The output of the machine was approximately 2.2 gallons per minute at a pressure of 300 pounds per square inch. The trees, about 50 to 60 feet tall, were moderately infested with the scale. Malathion, alone or with surfactant, was applied to four trees on July 11. On August 11, the trees were resprayed and other trees were sprayed for the first time. Scale mortalities were recorded on September 12.

## Results and Discussion

With hand-gun spraying (Table I), two applications of malathion or Diazinon, spaced about one month apart, gave perfect control of the scale when directed against the nymphs. A single application of either of these chemicals in mid August, after hatching was completed but before oviposition commenced, did not give satisfactory control even at the high dosage of six pounds of 25 per cent wettable powder per 100 gallons of spray. Evidently malathion and Diazinon are very toxic to the nymphs but are less effective against the mature scales. No records were made of the numbers of scales killed by the July sprays alone. However, Schread (1954) found that malathion is not an effective ovicide and that it is not sufficiently persistent to kill all the scales that hatch after treatment.

One application of lime-sulphur by hand-gun sprayer gave good control of the scale (Table I). The July spray at four per cent strength gave perfect control, the others nearly so. Peterson (1950) implies that dry lime-sulphur

TABLE I

Mortalities of the Pine Needle Scale on Ponderosa Pine on September 12, after
Various Insecticidal Sprays by Hand-gun Machine on Various Dates

| Material | Amount per 100 gal. | Date of application | Average mortality %[1] |
|---|---|---|---|
| Malathion, 25%[2]............... | 6 lb. | July 11 & Aug. 15 | 100.0 |
| Malathion, 25%............... | 2 lb. | July 11 & Aug. 15 | 100.0 |
| Diazinon, 25%[3]............... | 6 lb. | July 11 & Aug. 10 | 100.0 |
| Diazinon, 25%............... | 2 lb. | July 11 & Aug. 10 | 100.0 |
| Lime-sulphur[4]............... | 4 gal. | July 11 | 100.0 |
| Lime-sulphur............... | 8 gal. | Aug. 15 | 99.4 |
| Lime-sulphur............... | 2 gal. | July 11 | 98.7 |
| Malathion, 25%............... | 6 lb. | Aug. 15 | 92.8 |
| Diazinon, 25%............... | 6 lb. | Aug. 10 | 90.8 |
| Malathion, 25%............... | 2 lb. | Aug. 15 | 86.8 |
| Check....................... | No spray | — | 11.0 |

[1]Based on a total of 1,000 scales from 4 trees.
[2]Wettable powder; Pennsylvania Salt Manufacturing Company, Tacoma, Wash.
[3]0, O-diethyl-0-[2-isopropyl-4-methyl-pyrimidyl (6)] thiophosphate, wettable powder; Geigy Agricultural Chemicals, Bayonne, N.J.
[4]Liquid, specific gravity 1.28; Oliver Chemical Company, Penticton, B.C.

does not give satisfactory control of the mature scale, but the foregoing results
indicate that the liquid formulation is effective against all stages of the insect.

To avoid possible injury to the trees, it is usually recommended that lime-
sulphur be applied in the spring when the weather is cool and the evergreens
dormant (Felt and Rankin, 1938; McDowell *et al.*, 1955). However, Peterson
(1950) recommends dry lime-sulphur at one pound per 12 gallons of water in
June provided the temperature is not above 75°F., and Neiswander (1951)
reported that ten per cent liquid lime-sulphur was non-injurious to spruce even
in "relatively warm weather". In the present experiments, no observable injury
occurred to ponderosa pine trees when liquid lime-sulphur was applied at four
per cent strength in mid July or at eight per cent strength in mid August.
Temperatures at time of application were 85° and 87°F., respectively. Appar-
ently the hazards of lime-sulphur on some species of evergreens has been over-
emphasized.

With concentrate spraying (Table II), two applications of malathion, alone
or with surfactant, spaced one month apart and directed against the nymphs, gave
perfect control of the scale. A single application of any of these mixtures on

TABLE II

Mortalities of the Pine Needle Scale on Ponderosa Pine on September 12, after
Various Insecticidal Sprays by Concentrate Machine on Various Dates

| Material | Amount per 100 gal. | Date of application | Average mortality %[1] |
|---|---|---|---|
| Malathion, 25%[2]............... | 20 lb. | July 11 & Aug. 11 | 100.0 |
| Malathion, 25%............... | 20 lb. | July 11 & Aug. 11 | 100.0 |
| Colloidal Spray Modifier[3]....... | 1 qt. | | |
| Malathion, 25%............... | 20 lb. | Aug. 11 | 94.0 |
| Colloidal Spray Modifier........ | 1 qt. | | |
| Malathion, 25%............... | 20 lb. | Aug. 11 | 90.8 |
| Check....................... | No spray | — | 11.0 |

[1]Based on a total of 1,000 scales from 4 trees.
[2]Wettable powder; Pennsylvania Salt Manufacturing Company, Tacoma, Wash.
[3]A non-ionic, water-soluble surfactant; Colloidal Products Corporation, San Francisco, Calif.

August 11 was less effective, evidently because some of the scales that hatched in June had reached maturity and were difficult to kill.

The maximum height attained by the sprays, in perfectly calm weather, was approximately 30 feet with the hand-gun sprayer and 60 feet with the concentrate machine. A special air-vent is now available for a locally made concentrate sprayer. It allows operators to spray trees up to about 90 feet in height.

### Acknowledgments

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### References

Felt, E. P., and W. H. Rankin. 1938. Insects and diseases of ornamental trees and shrubs. The Macmillan Company, New York, N.Y.

McDowell, D. N., E. L. Chambers, D. V. Jensen, H. E. Halliday, G. E. Hafstad, P. W. Smith, and R. C. Wilkinson. 1955. Pests and diseases of trees and shrubs. Wisconsin State Dept. Agr. Bull. 330.

Neiswander, R. B. 1951. Controls for pine needle scale. Ohio Farm and Home Research 36 (268): 10-11.

Peterson, L. O. T. 1950. Control of the pine needle scale in the Prairie Provinces. Canada Dept. Agr., Div. Ent. Processed Publication No. 121.

Schread, J. C. 1954. Scale insects and their control. Connecticut Agr. Expt. Sta. Bull. 578.

# Effects of Hydrogen Ion Concentration on Hatching of Eggs of *Aplomya caesar* (Ald.) (Diptera: Tachinidae)[1]

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It has long been known that the juices of the digestive tracts of lepidopterous larvae initiate action within the micro eggs of tachinid parasites that results in hatching (Severin *et al.*, 1915). The effect of the alkalinity of the digestive juices of larvae of the European corn borer, *Pyrausta nubilalis* (Hbn.), on hatching of eggs of *Aplomya caesar* (Ald.) was mentioned in an earlier paper (Wishart, 1945). More detailed work has revealed more clearly the critical nature of this relationship.

*A. caesar* is a tachinid parasite that lays a microtype egg and develops on a relatively small number of species of about 10 genera of Lepidoptera. The eggs are laid on damaged plant tissues, particularly where insects have been feeding. Each female parasite may lay about 1,000 eggs. They are laid on a very wide variety of plants separated as far taxonomically as spruce and corn, and must therefore be eaten by a very great variety of phytophagous insects.

The chorion of the egg of *A. caesar* is chitinous dorsally and subchitinous underneath. Where the two parts meet there is a line of cleavage and very light pressure is required to remove the whole chorion. Most eggs are freed of the chorion as they pass the mandibles of the host, but those that reach the digestive tract still bearing the chorion hatch almost as readily as those that have lost it. Hatching takes place in the foregut or forepart of the midgut of the corn borer larva within about 15 minutes after the eggs are eaten. The parasite larvae then make their way through the gut to the body cavity. Eggs that do not hatch in these portions of the gut are excreted. Since only those larvae that enter the body cavity can develop, hatching during the short period the eggs remain in the forepart of the digestive tract is essential to survival.

## Materials and Methods

Eggs for experimentation were obtained by dissection of gravid females; each female yielded several hundred mature eggs. Hatching was first obtained by placing eggs under a cover slip on a microscope slide flooded with distilled water. Sufficient pressure was applied to the cover slip to crack the chorion as when the eggs are eaten by insects. At the edge of the cover slip was placed a drop or two of five per cent potassium hydroxide. As the alkaline solution diffused under the cover slip and reached the eggs, the larvae became active and each rapidly made a hole in the vitelline membrane with its bucco-pharyngeal hooks and freed itself. Hatching was rapid under these conditions, when it occurred. It was presumed, therefore, that hatching occurred when the diffusion of the strong alkaline solution into the distilled water provided the precise degree of alkalinity required.

To determine this degree of alkalinity eggs were exposed to potassium hyroxide solutions of pH 8.00 to 13.00 in gradations of .25, a Beckman pH meter being used for testing; solutions were allowed to stand for a few days and were rechecked as the hydrogen ion concentration changed somewhat in the first 24 hours. Samples of each of the solutions were placed in the depressions of a glazed porcelain plate; in each sample was placed a pair of cover slips between which were about 50 eggs of *A. caesar*. The hatching of the eggs was observed through a binocular microscope.

## Results and Discussion

Almost all the eggs hatched in about 15 minutes in solutions of pH 11.75 to 12.50. This period is approximately the same as that in which hatching occurs in the gut of the corn borer larva. Some hatching occurred at a pH as low as 9.00 but took much longer. At concentrations above 12.50 the larvae became very active, made their way part way through the membrane, and died. In solutions in which hatching was most rapid the larvae were active and apparently normal for over an hour after hatching.

Digestive juices of quickly dissected corn borer larvae were within the range in which hatching was most rapid in the test solutions. Waterhouse (1949) tabulated the pH values of the juices of the midguts of larvae of 39 species of Lepidoptera of 22 genera, the highest pH being 10.20. None of the species listed is a known host of *A. caesar* and none of the genera is represented in the host list of *A. caesar*.

The list given by Waterhouse (loc. cit.) shows that the hydrogen ion concentration required to hatch the eggs of *A. caesar* quickly is not common. Such a requirement must limit greatly the number of hosts that are suitable to *A. caesar* among the great number of species that must eat its eggs. Of all the limiting factors that the prospective hosts may present to *A. caesar*, the digestive juices are the first encountered and, perhaps, the most important. The high alkalinity requirement probably explains why this parasite has such a relatively small number of hosts.

## References

Severin, H. H. P., H. C. Severin, and W. Hartung. 1915. The stimulii which cause the eggs of the leaf-ovipositing Tachinidae to hatch. *Psyche* 22: 132-137.

Waterhouse, D. F. 1949. The hydrogen ion concentration in the alimentary canal of larval and adult Lepidoptera. *Australian J. Sci. Res., B*, 2: 428-437.

Wishart, G. 1945. *Aplomya caesar* (Aldrich), a tachinid parasite of the European corn borer. *Canadian Ent.* 77: 157-167.

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